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FIRST OUTLINES

OF

INORGANIC

CHEMISTRY.

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PREFACE.

This Treatise is more especially intended for those who have not the means or opportunity of consulting the larger works on the science. Keeping this object in view, the Author has endeavoured to unfold his subject gradually, as well as systematically, by proceeding from what is known to what is unknown, and explaining all technical terms and phrases as the necessity for their use arises. It is, however, assumed, at the outset, that the student is acquainted with the rudiments of decimal arithmetic, this being absolutely essential to any person who enters upon the study of natural philosophy. If not master of this necessary preliminary, half-an-hour's careful perusal of the subject "decimals," in a well-written arithmetic, will put him in possession of all that can be needed. If the student will carefully read through this Treatise twice, he will, it is believed, (especially if he have the opportunity of witnessing a few of the more simple experiments,) be able to understand most of the processes of the arts which depend upon chemistry, or to read with profit the higher works on the subject. If he desire to experiment himself, he will find a few hints in the chapter on Manipulation, which will show him how to do so at a small expense. This chapter, though not strictly belonging to the subject, the Author was induced to add, from the difficulties which by experience he knows are likely to obstruct the progress of the student.

CHEMISTRY.

◆

CHAP. I.

INTRODUCTORY.

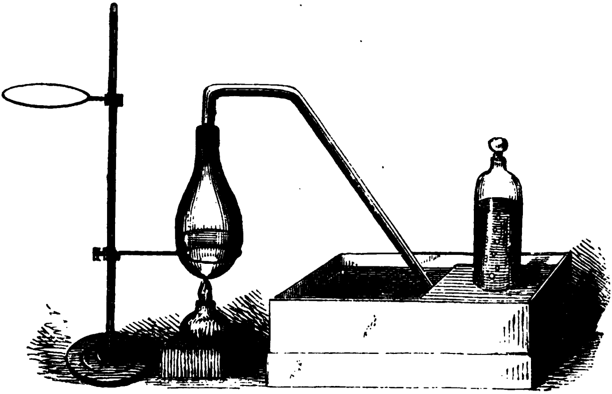
(1.) When a fire is kindled, or a candle lighted, we know that the materials of which they are composed gradually disappear; and if we ask what has become of them, we are told they are burnt; and that is usually supposed to be quite a sufficient account of them. If, however, we want to discover something more about the burning of a fire or a candle, than the simple fact of the disappearance of the combustible material; if, for example, we ask, Why is air necessary to support the flame? and why do the substances disappear? are they destroyed altogether; or, which is the fact, merely transformed into gases, and so escaping by the chimney or mingling in the air, are lost to observation? We can answer these questions by experiments; we must make, that is, certain trials upon burning bodies, with a view to find what part of the air is consumed by their burning in it, and what are the results of their combustion.

(2.) We may easily try an experiment of this class with the following simple apparatus: Procure a bell-glass, with an opening at the top, to be closed by a cork; pierce the cork with a wire, to which fasten a small portion of a wax taper; set the glass with its mouth downwards in a saucer of water, and then introduce the lighted taper; the taper after a little while will go out, as

would be properly observed, for want of air. The rising of the water in the jar will show the quantity of air that has disappeared. It must be observed, in the first place, that the air is not totally consumed, not even a fifth part has disappeared, while what remains is totally unfit to support flame, for another lighted taper plunged into the jar is instantly extinguished. If for the taper we were to substitute some phosphorus (Art. 117) contained in a little cup at the end of the wire, and after having kindled it introduce it into another jar, it will burn with a yellowish flame, producing a white smoke, which will collect in white flakes upon the cool surfaces of the jar. These white flakes will speedily become liquid from the moisture of the air, and will make the water in the basin in which the jar stands exceedingly sour; as the jar cools, the water will rise in it, and fill just a fifth part. The remainder of the air in the jar will be found to be unable to support flame, so that all burning combustibles are instantly extinguished in it; it is colourless, and without smell when quite pure, (though prepared as above, it has a slight odour of phosphorus,) and, in a word, will be found to consist of the gas called NITROGEN. The peculiar advantage of using phosphorus is, that it removes all the air which is capable of supporting flame, which a taper would not do.

(3.) We have then plainly made out that the air we breathe consists of two airs or gases, one of which supports combustion, or in which lighted fuel burns, while the other is neither a supporter of combustion nor a combustible; other substances will not burn in it, neither does it burn itself.

(4.) The next point to be inquired into is, What is the nature of that portion of the air which supports combustion? How can we obtain it pure and unmixed, or in chemical language, how shall we isolate it? Suppose we take some quicksilver or mercury, and heat it in a confined portion of air, till it does not quite boil, it will be very slowly converted from a brilliant liquid metal to a reddish-brown powder, leaving the incombustible nitrogen in the jar. It would, however, never take away all that part of the air in which the combustibles burn, though any quantity of mercury may be converted into the red substance, by continually allowing the access of fresh portions of air. This in fact is the way in which this *peroxide of mercury*, as it is called, is prepared on the large scale. Put then some of this red oxide of mercury into a flask, insert a bent



tube into the mouth of the flask through a cork, so as to be quite air tight; fill a jar perfectly with water, and place it upon a shelf with its mouth downwards and under water in a convenient vessel (a foot-bath will answer very well); then allow the gas, which will be found to escape on heating the flask, to bubble up into the jar, rejecting that which comes over first, as it is contaminated with the common air in the flask. It will be found, that the red substance will be resolved, by a heat a little *below redness*, entirely into gas, which is collected in the jar, and vapour of quicksilver, which condenses into little metallic globules in the cooler part of the apparatus. Hence, we can have little doubt that this gas is that part of common air in which combustibles burn. A few experiments will prove this to be the fact. A taper burns in it as it does in common air, though with greatly increased splendour. If it be blown out, and when the wick is still glowing, immersed in the gas, it will be rekindled. Phosphorus burns with a most splendid light, and produces the white flakes before noticed. Sulphur or brimstone burns in it with a beautiful violet light, producing an odour which, when the jar is opened, will be at once recognised as that of burning brimstone. This gas is known by the name of OXYGEN. Last of all, if any further proof be required that oxygen gas is the supporter of combustion in the air around us, we have merely to fill a jar four-fifths full of nitrogen and one-fifth oxygen, and we shall find its contents to be in every respect the same as common air.

Hence, then, the air we breathe, must consist of one measure of oxygen gas to four measures of nitrogen, of which the oxygen alone is efficient in supporting combustion.

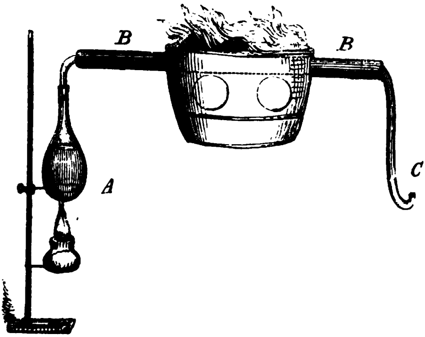
(5.) Oxygen was termed by its first discoverer, empyreal air, it being supposed that the air was pure and healthy in proportion to the amount of oxygen it contains. This, however, by no means appears to be the case; and were the proportion of oxygen to rise much above or fall much below one-fifth of the whole bulk of air, the consequences would be equally fatal. In the former case we should, so to speak, *live too fast*, and shortly die in a high state of fever; in the latter case be suffocated; and it appears, that the proportion of oxygen to nitrogen in the atmosphere, is scarcely subject to variation at all. Moreover, it appears, that though the nitrogen is respired unchanged, yet no gas can be substituted for it, even though the attempt be made with gases, which when mixed with due proportion of oxygen seem to have no injurious effect upon the lungs.

(6.) We must partially defer the consideration of the products of combustion to a later part of this treatise; as to investigate them thoroughly, would require a deeper acquaintance with the chemistry of the combustible, than can be supposed at present to be possessed by the student.

There is one product, however, which though it may be imagined an unlikely one, will be recognised as being really produced by our candles and gas flames; and this is no other than water.

(7.) If we place a cold lamp glass over a burning oil or gas flame, we cannot fail to observe that the glass is instantly dimmed with a deposition of dew, which disappears again as the glass gets hot. If, however, the heated vapours which arise from a gas jet, be conveyed through a long cooled tube, this condensation is permanent; and as may be observed in cold weather, in London and other large towns, a chimney from a gas burner will drip with an acid liquor, which, on examination, will be found to be neither more nor less than *water*, contaminated for the most part with certain acids, called the carbonic and sulphuric acids. Hence then, strange as it may appear, the fire of a gas flame (and the same may be said of most of those substances we use for fuel and heat) produces water. Yet, perhaps, the surprise of those who are made acquainted with this fact for the first time, may be in some degree moderated, if they reflect that possibly the very reason why water so effectually extinguishes fire, is because it contains something which being burnt already has no tendency to burn again. And this will be found to be the fact.

(8.) How then shall we isolate this combustible substance, which (it seems likely) exists in water? For this purpose we may use a method, nearly the same in principle as that by which we isolated oxygen, only we must use another metal instead of mercury, namely, iron. A tube of iron or

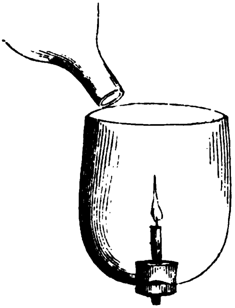


porcelain is so arranged in a furnace, that the middle, previously filled nearly full of iron filings and turnings, can be made hot; there is a flask of water with a spirit lamp A at one end, and a delivery tube C at the other end of the tube B B, as represented in the figure. As soon as the centre of the tube is red hot, the water in the flask is made to boil, and as the steam passes through the tube, the water is decomposed by the iron; and an inflammable gas, which may be collected over water, issues from the delivery tube. When the operation is over, the iron, on opening the tube, will be found to be converted into a black powdery substance, called oxide of iron, and to have increased in weight. A more convenient method of preparing this gas will be given hereafter.

(9.) On collecting the gas in a jar we find it to be colourless, inodorous, tasteless, very light, and combustible, burning with a pale blue flame, scarcely visible in daylight, yet very hot; the product of its combustion being (when proper precautions are taken) nothing but pure water. It does not, however, produce water by *merely* mixing in proper proportions with oxygen; but if we mix two parts by measure of this gas, and one of oxygen, in a very strong tube, and then apply a light, an explosion takes place, and the inside is immediately covered with a dewlike deposit of water. From this circumstance this gas is called HYDROGEN, which means water-producer. It will be observed by the student, that there is an essential difference in the constitution of water as compared with that of common air. Water is a *combination*, and not a *mixture* of its elements; atmospheric air is a *mixture*, and not a *combination*; and this distinction, as will hereafter appear, is most important.

(10.) We find, then, that water is one of the results of combustion of an ordinary fire or candle, and the reason why it is not detected is, that it escapes in the form of steam or vapour, which is dissolved in the hot nitrogen, and other gases, arising from the fire, and so eludes observation, unless special means are used to detect it.

(11.) There is, however, another gas which is produced by our fires, which, though invisible, yet not being inodorous, may be detected by the smell. This may be best observed in the peculiar odour which arises from burning charcoal. The collection of the gas is very easy; we have nothing more to do than introduce a piece of lighted charcoal, at the end of a wire, into a bottle of oxygen. The charcoal glows with a brilliant light, and, when the action is over, the bulk and appearance of the gas in the bottle is not at all altered, though its properties are singularly different to either common air, or oxygen. It instantly extinguishes flame; it is incombustible, and very heavy, so much so, as to be capable of being poured from vessel to vessel, like water; an experiment which is easily shown by putting a taper at the bottom of a jar, and pouring in the gas from another vessel, when the taper is instantly extinguished; nor can it be relighted until the gas is allowed to run out, as by opening the bottom of the jar. This gas has distinctly acid properties; it dissolves in water, and the solution tastes slightly sour, and reddens blue litmus



paper. This may be shown by putting a little water into the bottom of a vessel containing it, and then shaking it well. The water speedily absorbs the gas, and, on opening the bottle, the air is heard to rush in; consequently this gas cannot be kept over water. It is called CARBONIC ACID, *carbo* being the Latin for a piece of charcoal, or a coal.

(12.) The great weight of carbonic acid, when compared with common air, will enable us to answer the question, What has become of the combustible material? The whole is for the most part resolved into carbonic acid and steam, and the gases which escape up the chimney are (other things being the same) *heavier* than the air which entered the fire; and, when we come to weight and measure, we shall find the *loss* of weight in the fuel is exactly equal to this *gain* of weight in the gases produced.

(13.) Thus, then, by reasoning and experimenting we come to the following conclusions: That by burning we lose nothing, the matter of the fuel merely taking other forms, and so eluding our observation. We have, moreover, become acquainted with four elements, as they are called; namely, OXYGEN, existing in our atmosphere, and the supporter of flame; NITROGEN, which serves to dilute the oxygen, and is not combustible; HYDROGEN, which exists in water, so that, in fact, water is burnt hydrogen; and CARBON, or charcoal, which produces the sour-tasting carbonic acid, by being burnt in oxygen. The reason why these are called elements will appear in the next chapter.

CHAPTER II.

SIMPLE SUBSTANCES, OR ELEMENTS.

(14.) All those substances which we are unable to resolve into simpler forms of matter, we term elements, or simple substances. Thus, oxygen, hydrogen, nitrogen, and carbon, are all termed elements, as we cannot resolve them into any simpler forms of matter; while water, or air, are not elements, being resolvable, the former into oxygen and hydrogen, the latter into oxygen and nitrogen. It does not follow that these elementary substances may not be resolved into simpler forms hereafter; possibly they may be, as the science of chemistry advances; but, as we cannot decompose them, we are justified for the present in considering them simple.

(15.) The number of elementary substances at present recognised is sixty-two, of which forty-seven are metals; the rest are termed nonmetallic. There is, however, no abrupt line of demarcation, for the two classes graduate into one another in the completest manner. Subjoined is a table containing the names of all the elements, metallic and nonmetallic. The former are divided into classes, for the convenience of reference hereafter. In Class VI. are two substances, arsenic and tellurium, which, though possessing the properties of metals, are yet intimately connected with the nonmetallic elements. Indeed, the student will observe, when we come to a detailed history of the elements, how their properties shade off in all directions as it were one into another.

I.—A TABLE OF ELEMENTARY SUBSTANCES.

I.	II.	III.	IV.	V.
Name.	Symbol.	Specific Gravity.	Equivalent.	Usual appearance.
Oxygen	O	(Air = 1.000) 1.1093	8	Permanent colourless gas; supporter of combustion.
Hydrogen	H	0.0694	1	Permanent colourless gas; combustible.
Nitrogen	N	0.9706	14	Permanent colourless gas; scarcely combustible.
Chlorine	Cl	2.395	36	Pale green gas; supports combustion; absorbable by water.
Iodine	I	(Water = 1.000) 4.9480	126	Black scales, rising in purple vapour when hot.
Bromine	Br	2.9800	78	Dark volatile red fluid.
Fluorine	F	—	19	Never been isolated; probably a gas.
Carbon	C	3.5000	6	Black, solid, and *diamond.*
Silicon	Si	—	15	Dark brown powder.
Boron	B	—	11	Deep olive powder.
Sulphur	S	2.0000	16	Pale yellow solid.
Selenium	Se	4.3100	40	Brown metallic solid.
Phosphorus.........	P	1.7500	32	Like unbleached wax.

METALS.

CLASS I.—METALS OF THE ALKALIES. BASIC.

Name.	Symbol.	Specific Gravity.	Equivalent.	Usual appearance.
Potassium......... [Kalium]	K	0.865	40	Very soft silver-white metal; inflames on contact with water.
Sodium .... [Natrium].........	Na	0.9722	24	Not quite so soft as potassium.
Lithium	L	—	7	Very scarce; alkaline metal, like the above.

CLASS II.—METALS OF THE ALKALINE EARTHS.

Name.	Symbol.	Specific Gravity.	Equivalent.	Usual appearance.
Barium	Ba	—	69	Silver-white; prepared with great difficulty.
Strontium	Sr	—	44	White heavy metal.
Calcium	Ca	—	20	As above; prepared with great difficulty; the oxide is lime.
Magnesium.........	Mg	—	12	Silver-white; the oxide is magnesia.

CLASS III.—METALS OF THE EARTHS.

Name.	Symbol.	Specific Gravity.	Equivalent.	Usual appearance.
Aluminum	Al	—	14	Platinum-coloured powder; its oxide is pure clay.
Glucinum	G	—	5	All these are found in very rare minerals; where they have been isolated they are like aluminum.
Yttrium	Y	—	32	
Erbium	Er	—	—	
Terbium	Te	—	—	
Zirconium	Z	—	23	
Norium	No	—	—	
Thorium............	Th	—	60	
Cerium	Ce	—	—	
Lanthanum........	La	—	—	
Didymium	Dy	—	—	

CLASS IV.—METALS FORMING BASES, BUT NOT ACIDS.

Zinc	Zn	6.9154	32	Bluish white.
Cadmium	Cd	8.6355	56	Like tin, but harder.
Bismuth	Bi	9.8220	213	White, with a faint tint of pink.
Cobalt	Co	8.5384	30	White and brittle; used for staining glass blue.
Copper .... [Cuprum]	Cu	8.7210	32	Red.
Nickel................	Ni	8.6370	28	Silver-white; with copper forms German silver.

CLASS V.—METALS FORMING STRONG BASES AND ACIDS.

Iron .... [Ferrum]	Fe	7.8493	28	Greyish.
Manganese	Mn	8.000	28	Greyish white; extensively employed as peroxide.
Chromium	Cr	5.90	28	Greyish white; used in dyeing.
Lead .... [Plumbum]	Pb	10.3889	104	Bluish white.
Uranium	U	9.000	60	Black powder, or white malleable metal.

CLASS VI.—METALS FORMING WEAK BASES OR ACIDS.

Name.	Symbol.	Specific Gravity.	Equivalent.	Usual appearance.
Vanadium	V	—	68	White, brittle, very infusible.
Tungsten .... [*Woolframium*]..	W	17.40	100	White, hard, brittle, & infusible.
Molybdenum	Mo	8.60	48	Whitish metal, difficult of fusion.
Columbium .... [*Tantalum*]	Ta	—	185	Grey metal.
Niobium	Ni	—	—	
Pelopium	Pe	—	—	
Titanium...........	Ti	—	24	Brilliant, hard, copper-coloured.
Tin .... [Stannum]........	Sn	—	59	Silver-white.
Osmium..............	Os	10.0	140	Black powder.
Tellurium	Te	—	64	Colour and lustre of silver.
Antimony .... [Stibium]	Sb	—	129	Bluish white, very brittle.
Arsenic	As	5.9590	75	Greyish white, brittle; its vapour has the odour of garlic.

METALS OF WHICH THE OXIDES ARE REDUCIBLE BY HEAT.—NOBLE METALS.

Gold .... [Aurum]	Au	19.20	200	Bright yellow.
Mercury............ [Hydrargyrum] .	Hg	13.559	100	Fluid at ordinary temperatures.
Silver .... [Argentum]	Ag	10.428	108	Brilliant white.
Platinum	Pt	21.50	99	Not so white as silver, though much resembling it.
Palladium	Pd	11.50	54	Dull white, hard, and malleable.
Iridium	Ir	18.63	99	Whitish.
Ruthenium	Ru	—	51	
Rhodium	R	11.20	52	White; difficultly fusible; very hard.

The Elements whose names are printed in italics are scarce, and have been applied to no use.

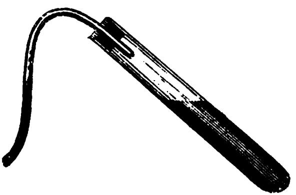
(16.) In the preceding table the name of the element is given in Col. I. Col. II. contains the symbols, which usually consists of the first letter of the name of the substance, or, when two begin with the same letter, the first and some other distinctive letter; in some cases the symbol is taken from the Latin name, which is then added in brackets. Col. IV. contains a number to be hereafter explained, called the equivalent. Col. V. contains a short description of the general appearance, as it usually occurs; in the case of the metals, a metallic lustre is supposed to accompany the colour, unless otherwise stated. In Col. III. is given the specific gravity, water being 1.000; or, in the case of the first four which are gases, air being 1.000. Those who are ignorant of the meaning of the term specific gravity may still obtain an idea of the weights of equal bulks of different substances, by comparing the numbers against them with that against substances which are familiar to them; the greater the number before the dot, the heavier the metal, or other substance. Thus bismuth is a much heavier, and arsenic a much lighter metal than iron, while potassium and sodium are absolutely lighter than water, and float upon its surface.

We now proceed to examine the nonmetallic elements in detail, and we shall commence with oxygen.

OXYGEN.—O 8.

(17.) The method given in the introductory chapter for the separation of this gas is not economical. A better method is to heat, in a retort or flask, some of the salt called chlorate of potash;

it is advisable to add a little peroxide of manganese, as the gas is then given off at a far lower temperature than when the chlorate is heated alone. The heat decomposes the salt, and converts it into chloride of potassium and oxygen; the manganese remains unaltered; the gas is very pure. Another, and more economical method, is to put some peroxide of manganese into a piece of large gas tube, closed at one end; the other being filled with a perforated cork and delivery tube of glass, or, preferably, flexible metal tube, as shown in the figure. On heating the manganese red-hot, a plentiful supply of oxygen is given off, not, however, very pure. A brown powder, which is sesquioxide of manganese, remains in the tube. These reactions cannot be explained at present.*



(18.) Pure oxygen is a tasteless, inodorous, colourless gas; specific gravity, 1.1057; 100 cubic inches weigh 34.38 grains. It is therefore a little heavier than common air. It supports flame, substances burning in it as in common air, though much more brilliantly; some which are usually considered incombustible burn in oxygen, as, for example, an iron wire. For the purpose of making this experiment a watch spring, or piece of pianoforte wire should be passed through a good cork, its end being previously dipped in melted brimstone. The brimstone being then lighted, is plunged into a jar of oxygen gas, the cork fitting into its stopper-hole. The iron burns brilliantly, and drops down as a scaly black substance, which is oxide of iron. The existence of free oxygen is detected by introducing a glowing match into the gas to be examined: if it be oxygen, the match is rekindled.

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* In the first case, $KO + Cl\,O^5$ is resolved into $K\,Cl$, and O^6 escapes; in the latter. $2\,(Mn\,O^2)$ becomes $Mn^2\,O^3 + O$.

(19.) Oxygen, with one exception, unites with all the other elements. These combinations are, strictly speaking, called *oxides*, though that name is usually confined to those of its compounds which are not acid, as many are.

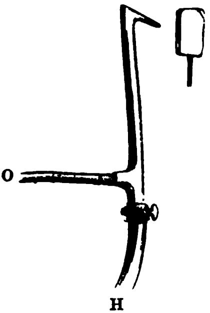
(20.) A great deal, of course, depends upon the *quantity* of oxygen which a compound contains, so much so, that compounds of the same element, with different proportions of oxygen, are often more different than those of different elements in the same proportion: thus the metal manganese, united with one proportion of oxygen, is a *base* showing a strong disposition to unite with acids; with another, a very *neutral* and *inert* substance; with a third, is an *acid* which unites with bases, so that opposite characters are conferred by union with different proportions of oxygen.

(21.) In consequence of this it is necessary that each compound should have a name which should distinguish it from other compounds of the same elements. This is effected in the following manner:—Usually, the proportions of oxygen are as the numbers 1, 2, 3, &c.; that is, the oxide of manganese, above spoken of, which unites with acids, contains 8 grains of oxygen to 28 grains of manganese. The second or neutral compound contains 16 grains of oxygen to 28 manganese. The third or acid compound contains 24 grains oxygen, to 28 manganese. Now, the first is called *pro*toxide; that is, *first* oxide; the second, *deut*-oxide, or *second* oxide, (or in this case more usually *per*oxide, which means *complete* oxide, because this is the last oxide which is not acid.) The acid compound is called manganes*ic*, or, for shortness, mangan*ic* acid. If an acid compound should be discovered, containing *less* oxygen than manganic it would be called mangan*ous* acid. The termination *ous* denoting a less, and *ic* the higher, degree of oxidizement. The same principles apply to the other elements, such as chlorine, iodine, bromine, sulphur, &c. with scarcely any variation.

HYDROGEN.—H 1.

(22.) Hydrogen may best be obtained by the action of iron or zinc on dilute sulphuric acid. For this purpose, some iron nails or filings, or shreds of zinc, or the metal granulated by pouring into water when melted, may be put into a flask or bottle, and covered with oil of vitriol, diluted with six or eight times its bulk of water. The liquid becomes hot, and the gas is given off from the surface of the metal with effervescence. The hydrogen thus obtained is never quite pure. It has a disagreeable smell, especially when prepared from iron.

(23.) Hydrogen, when quite pure, has neither colour, taste, nor smell. It is very light: specific gravity 0.0694; 100 cubic inches weigh 2.10 grains. It may be respired for a short time, though it is instantly fatal to small animals. It is very combustible, burning with little light and great heat. Its lightness and combustibility may be illustrated by filling a bladder with hydrogen, and then affixing a tobacco-pipe so as to be able to fill soap bubbles with it. These ascend rapidly, and on applying a taper to them, they burn. If, instead of pure hydrogen, we use a mixture of hydrogen and oxygen in proportion to form water, a violent explosion is the result. Three volumes of air and one of hydrogen also give a very loud report. The heat of the flame of hydrogen, when urged by a blast of oxygen, is very great. For this purpose the hydrogen and oxygen are usually contained in separate vessels, and only allowed to mix as they enter the jet at which they are to be burned. If they are mixed beforehand, which must then be in the proportion of 1 oxygen to 2 hydrogen, by measure, there is danger of an explosion, which may be very serious, especially if the quantity of gas be large. Platinum, and other substances quite infusible in a common furnace, melt readily in the flame of the oxyhydrogen blow-pipe. The flame, though hot, gives very little light when by itself; but if it be projected against a piece of lime, it instantly glows with a light like the sun. This is the light made use of in the gas microscope.



(24.) The effect of certain of the metals, and more especially platinum, on a mixture of oxygen and hydrogen, is curious. If a perfectly clean piece of platinum foil be introduced into the mixed gases, drops of water speedily appear on its surface, and the metal becomes hot. If it be very thin, it will become red-hot, or even white-hot, when the gases explode. Platinum black, which is platinum in a minute state of division, produces the same effect. Gold, and even stones and glass, possess this property, but in a lower degree, and do not show it till assisted by heat. The explanation of this is that the platinum is *wetted* by the oxygen and hydrogen, and by the condensation the gases are brought within the influence of each other's attraction. A glass tube, open at both ends, held over a flame of hydrogen, produces a musical note. This arises from a series of rapid and minute explosions.

(25.) The combustion or combination of hydrogen and oxygen, invariably produces water; hence, water is an oxide of hydrogen,—its symbol is HO, and its equivalent 9.*

Pure water is colourless, tasteless, and inodorous. We have already noticed abundance of experiments, which prove it to be composed by weight, of 8 parts oxygen, and 1 hydrogen. Its composition therefore stands thus:—

	Atoms.	Weights.	per Cent.	Vol.
Hydrogen	1	1	11.1	1
Oxygen	1	8	88.9	½
Water	1	9	100	1

(26.) It is seldom that water is found pure in nature, being generally contaminated with substances dissolved from the earth in the case of spring-water, and from the air in rain-water. These substances it is which make spring-water hard. If pure water be required, it must be obtained by distillation. The figure below represents a still: A is a boiler, which may be set in a furnace or even placed on an ordinary fire; B is the still head, which fits tightly into the boiler; C is a tub, containing a twisted pipe usually called a worm; C is filled with cold water, when the steam which rises in B is condensed in the worm and runs out at the tap; that which comes over first must be rejected; the cold water in C must be replenished as it gets hot. Water thus obtained is not quite pure, though sufficiently so for most purposes; if very great purity be required, it is to be redistilled in perfectly clean vessels of silver.

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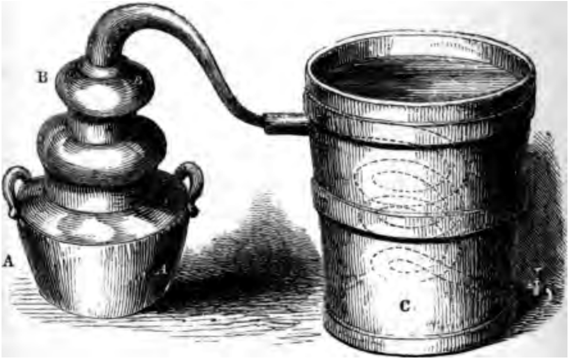
* This term is explained in Art. 137.



(27.) In consequence of the ease with which it is obtained pure, it is assumed as the standard of specific gravity.* The specific gravity of a substance, is the proportion of its weight to the weight of an equal bulk of water. Thus, for example:—A cube of gold an inch in the side, would weigh 19 times as much as the same bulk of water; therefore the specific gravity of gold is said to be 19. The weight of a given substance may be found from the table of specific gravity, if we remember that a cubic foot of water weighs 1,000 ounces, a cubic foot of gold therefore would weigh 19,000 ounces, of iron 7,780, or 480 lbs.

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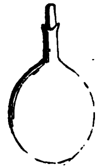
* See the Treatise on Mechanics, by Rev. H. Moseley, published by the Society for a detailed account of the method of taking specific gravities.

(28.) The specific gravity of most solids has been determined, and an extensive table is given in the work of Moseley, referred to. The method of taking the specific gravity of liquids is, however, of so frequent occurrence in chemistry, that we explain it here. A bottle is constructed which exactly holds 1,000 grains of distilled water, and provided with a counterpoise to balance it when empty; it is filled with the liquid, the specific gravity of which is to be determined, and put into one scale, the counterpoise into the other; the number of grains to be thrown in to restore the balance will be the specific gravity required. Thus, for example,—suppose we wished to know the specific gravity of sea, as compared with distilled water, the number of grains the bottle would hold, would be 1,027 grs.; and hence, the specific gravity of sea water is 1.027. It is usual to compare the specific gravity of gases with air. (See Art. 53.)



(29.) Water freezes at 32°, and boils at 212°. It presents too a remarkable exception to the generality of fluids, which expand uniformly as they are heated from their freezing to their boiling points. If the bulb of a water thermometer, at a temperature of 60°, were immersed in ice, we should find that the water would contract, gradually sinking in the tube till cooled to about 40°, when it would begin to expand, rising again until it froze. The important natural consequences of this exception to the general rule are very great. Were it not for this, our rivers, and more especially our ponds and lakes, would in hard winters be converted into a mass of ice, which the heat of summer would scarcely melt. As it is, the water in a frost cools down to 40°, the upper and heavier strata sinking, and the warmer and lighter water from the bottom rising, when the temperature of the whole reaches 40°, then the stratum at the top becomes colder and lighter than the rest, floats, and gradually freezes into a comparatively thin stratum of ice.

(30.) Water in freezing, expands considerably and with immense force. Thus, for example, if water trickles into the cleft of a rock and there freezes, the force of its expansion will sometimes split the hardest materials, which fall down on the ensuing thaw. This happens frequently in the cliffs of Dover and the southern coast. It is exactly the same cause which crumbles the earth in ploughed lands, when turned up previous to a frost.

(31.) All gaseous bodies are absorbed more or less by water. Spring-water always contains common air and carbonic acid; this may be seen rising from the bottom of a glass of fresh spring-water in minute bubbles. The following is a table of the quantity of different gases absorbed by 100 volumes of water:

TABLE II.

I.	II.	III.	IV.	V.	VI.
Symbol.	Name.	100 vols. Water absorb	Tension of Vapour in Atmosphere.	Temperature.	
O	Oxygen	3.7			
H	Hydrogen	1.56			
N	Nitrogen	1.56			
NO^2	Nitric Oxide	5.00			
CO	Carbonic Oxide	2.0			
PH^3	Phosphuretted Hydrogen	2.14			
C^2H^2	Olefiant Gas	15.3	26.9	0°	
Cl	Chlorine	200.0	.4	60°	
ClO^4	Peroxide of Chlorine	700.0			
H Cl	Hydrochloric Acid	50,000.0	40	50°	
NO	Nitrous Oxide	100.0	50	45°	Freezes at 150° below 0.
NH^3	Ammonia	67,000.0	6.5	50°	
CO^2	Carbonic Acid	100.0	39	60°	Freezes at 90° below 0.
C^2N	Cyanogen	450.0	3	49°	
SO^2	Sulphurous Acid	3,000.0	liquid at 0°		Freezes.
SH	Sulphuretted Hydrogen	100.0	17	50°	
ScF^2	Fluosilicic Acid	35,000.0			
BF^3	Fluoboric Acid	70,000.0			
H Sl	Hydroselenic Acid	300.0			

Thus, 100 cubic inches of water, will absorb 1½ of hydrogen, 3 of oxygen, 100 or its own bulk of carbonic acid, and so on.

(32.) Water combines with many other bodies, particularly oxides of the metals, and the combinations are termed hydrates. Lime, for example, combines with water in slacking, and the *dry* powder which results, is called hydrate of lime. Water unites with some salts in crystallization, forming part of the solid substance of the salt. Alum in crystals, contains 45 per cent. of water in the solid state; this is termed *water of crystallization.*

(33.) PEROXIDE OF HYDROGEN. HO^2. 17.—When peroxide of barium is put into dilute hydrochloric acid, oxygen is evolved, which is absorbed by the water, and forms with it peroxide of hydrogen. The manipulations are excessively troublesome, and the liquid requires to be kept in ice. It possesses the aspect of a clear colourless transparent inodorous liquid, of remarkable bleaching powers; it is decomposed by the slightest elevation of temperature, and the contact of most metals. It consists probably of

	Atoms.	Weights.	per Cent.
Hydrogen	1	1	5.9
Oxygen	2	16	94.1
Peroxide of Hydrogen	1	17	100

It therefore contains twice as much oxygen as water; its symbol is HO^2.

NITROGEN.—N 14.

(34.) We have already seen that this gas may be prepared by burning phosphorus in a confined portion of air. A better method is to pass chlorine into strong liquid ammonia or hartshorn. For this purpose procure a wide-mouthed jar, stop the mouth with a bung, bore two holes in the bung, through which place two bent tubes, one proceeding from the flask in which the chlorine is generated, and dipping below the liquid in the bottle; the other, to serve as a delivery tube; on passing the chlorine into the hartshorn in the bottle, nearly pure nitrogen will be given off.* Care must be taken not to push the production of the gas too far, as then the dangerously explosive chloride of nitrogen will be produced.

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* $3Cl + NH^3 = 3HCl + N$.

(35.) Nitrogen is, when pure, without colour, taste, or smell; it is rather lighter than air; its specific gravity is 0.971; and 100 cubic inches weigh 30.15 grains; it is 14 times heavier than hydrogen; its symbol is N, and its equivalent 14.

(36.) It was formerly called *azote*, from a Greek word, signifying privation of life, since animals confined in it soon die. It is found to exist in nitre or saltpetre; hence it has been called nitrogen, or nitre generator, which is a better name than *azote;* for every gas whatever might be called *azote*, except common air, and with greater propriety, as nitrogen is almost as essential to our life as oxygen.

(37.) Nitrogen does not support combustion; burning bodies introduced into it are instantly extinguished; it is not combustible; if, however, it be mixed with 14 times its bulk of hydrogen, and set fire to at a jet, it does burn into nitric acid, —the heat of the hydrogen serving to burn it. The presence of water also tends to assist its formation. If sparks from an electrical machine be passed through a mixture of oxygen and nitrogen, (common air will do,) a very small quantity of nitric acid is produced, provided water be present.

(38.) **Nitrogen and Oxygen.**—There are five combinations of nitrogen with oxygen, viz. :—

Nitrous Oxide	$N O$
Nitric Oxide	$N O^2$
Hyponitrous Acid	$N O_3$
Nitrous Acid	$N O^4$
Nitric Acid	$N O^5$

(39.) **Nitrous Oxide, Protoxide of Nitrogen.** NO. 22.—When some of the salt, called nitrate of ammonia, is heated in a retort, exactly in a similar manner to that adopted for obtaining oxygen from chlorate of potash, it is resolved into water and protoxide of nitrogen.*

Protoxide of nitrogen is a colourless transparent gas, of a sweetish smell and taste; its specific gravity is 1.525, and 100 cubic inches weigh 47.29 grains. It supports the combustion of combustibles almost as readily as oxygen. It is absorbed by cold water to the extent of its own volume; hence it must be collected over tepid water. It can be breathed for a little while, and produces a remarkable intoxication, which is not, however, permanent. From this circumstance, it has been called laughing gas. Great care should be taken that the gas be quite pure, and especially that it be not contaminated with the compound of oxygen and nitrogen we are next to examine, if it is to be used for this experiment. It is hazardous when all precautions are taken, as its effect on some constitutions is very violent. Its composition is

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* $N O^5 + N H^3 = 3 H O + 2 NO.$

	Atoms.	Weights.	per Cent.	Vol.
Nitrogen	1	14	63.6	1
Oxygen	1	8	33.4	½
Nitrous Oxide . .	1	22	100	1

If it be passed through a red-hot tube, a measure of protoxide is resolved into a measure of nitrogen and half a measure of oxygen. Hence, the gas takes up less room than a mixture of its elements. This is very commonly the case. We may thus calculate its weight:—

			Weights.
100	cubic inches of	Nitrogen	30.166
50	„	Oxygen	17.054
100	„	Protoxide of Nitrogen	47.220

(40.) DEUTOXIDE OF NITROGEN. NITRIC OXIDE. NO^2. 30.—When nitric acid is poured upon copper filings or clippings, in a flask, and heat applied, at first red fumes appear; when, however, the air in the flask is expelled, a colourless gas makes its appearance, which may be collected over water. It is colourless; 100 cubic inches weigh 32.13 grains; specific gravity, 1.039. It extinguishes flame. Phosphorus, if well alight, burns in it, producing white flakes of phosphoric acid and nitrogen. Its symbol is NO^2. It contains twice as much oxygen as the protoxide. It is also decomposed when passed through a hot tube; in this case, it is resolved into a mixture of equal measures of oxygen and nitrogen, the bulk or volume remaining the same. Hence, we can calculate its weight thus:—

		Grains.
50 cubic inches of	Oxygen	15.08
50 „	Nitrogen	17.05
100 „	Deutoxide of Nitrogen	32.13

It is composed of

	Atoms.	Weights.	per Cent.	Vol.
Nitrogen	1	14	46.7	1
Oxygen	2	16	53.3	1
Nitric Oxide	3	30	100	2

The most characteristic property of deutoxide of nitrogen, is the formation of red fumes when mixed with air or oxygen. These are a mixture, probably, of the two next compounds, known as nitrous and hyponitrous acids.

(41.) Nitrous and Hyponitrous Acids, have not yet been sufficiently examined, and some doubt remains as to their real constitution. They are of little importance. A curious circumstance connected with the colour of these vapours deserves to be mentioned. When cooled down below a certain heat, 0° of Fahrenheit, it is colourless, while the hotter it is the deeper its colour; at 32° it is a pale yellow, at 60° a deep orange.

(42.) Nitric Acid. NO^5. 54.—All these compounds yield in importance to the next, namely, nitric acid, sometimes called aquafortis. It is obtained by heating a mixture of nitre or nitrate of soda with sulphuric acid,* (great quantities of it are daily prepared in London;) a liquid distils over, which is clear when quite pure, though sometimes of a red colour, from the presence of one or both the compounds last mentioned; it smokes when exposed to air; is excessively sour and caustic, staining the skin of a yellow colour, and ultimately destroying it; if poured upon powdered red-hot charcoal, it causes it to burn brilliantly; if mixed with warm oil of turpentine, it sets it on fire; when most highly concentrated, it has a specific gravity of 1.517, and boils at 180°; it mixes with water in all proportions; the strongest liquid acid consists of 54 parts acid and 9 water. Absolutely dry nitric acid has only very recently been isolated; it is prepared by passing perfectly dry chlorine over perfectly dry nitrate of silver; it resembles dry sulphuric acid; it consists of

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* $(NO^5 + KO) + (SO^3 + HO) = (SO^3 + KO) + (NO^5 + HO.)$

	Atoms.	Weights.	per Cent.
Nitrogen	1	14	25.9
Oxygen	5	40	74.1
Nitric Acid	1	54	100

and its symbol is NO^5. Liquid acid, specific gravity 1.5, is $NO^5 + HO$. Nitric acid is used extensively in the arts; it dissolves silver, copper, mercury, and most of the metals; mixed with hydrochloric acid, it dissolves gold and platina. It is curious that the stronger acid is in many cases not so efficient in dissolving the metals, as that which is weaker.

(43.) We have in these compounds an instance of the power of oxygen in forming both oxides and acids, and a further illustration of the terms protoxide, deutoxide, before alluded to. We see that 14 parts, by weight, of nitrogen combine with 8 parts, by weight, of oxygen, to form 22 parts, by weight, of *pro*toxide of nitrogen; with 16 parts, to form 30 parts of *deu*toxide; with 24 parts to form an acid which is called *hyponitrous* acid; with 32 parts to form another acid, which is called nitr*ous* acid; with 40 to form another, called nit*ric* acid. The two acids, nitrous and nitric, were first discovered, and hence, when an acid was discovered containing less oxygen than the nitrous, it was called hyponitrous, *hypo* being a Greek preposition, signifying deficiency.* Since 1 part, by weight, of hydrogen goes as far as 14 parts of nitrogen, in combining with 8 parts, by weight, of oxygen; and as these proportions are always preserved in the same substances, the reason of the term equivalent will be evident, and hence the numbers against the other substances.

(44.) AMMONIA, or TERHYDRURET OF NITROGEN. $NH^3.17$.—The next substance we have to examine is that compound of nitrogen and hydrogen called ammonia. It is the only compound of these two elements known, and consists of 14 parts nitrogen, and 3 hydrogen: its symbol, therefore, is NH^3 It may be obtained by mixing two parts sal ammoniac with one of dry quicklime;† and on applying heat a gas is given off, which must be collected over quicksilver, as it is largely and rapidly absorbed by water. The smell will remind us of hartshorn, which is, in fact, nothing but the solution of ammonia in water. Its name ammonia, is derived from Ammon—sal ammoniac being originally imported from the neighbourhood of the temple of Jupiter Ammon, in Africa. Pure ammoniacal gas is excessively pungent, colourless, and rapidly absorbable by water. It is unrespirable, of course, though the odour is pleasant and stimulating when sufficiently diluted with air. Its specific gravity is 0.5893; 100 cubic inches weigh 18 grains. It extinguishes flame, but is feebly combustible; mixed with its volume of oxygen, it explodes feebly. It is used in the arts, in a state of solution in water, for which purpose an apparatus is employed similar to that for generating nitrogen: only pure water must be put into the bottle, and equal parts of sal ammoniac and well burned quicklime (in this case, previously slacked) should be put into the flask; the weight of the water in the bottle should be equal to the weight of the sal ammoniac. Ammonia is composed of

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* The student is cautioned not to confound this with *hyper*, which is a different preposition, signifying the exact contrary of *hypo*, or redundancy.

† $(HCl + NH^3) + CaO = (HCl + CaO) + NH^3$.

	Atoms.	Weight.	per Cent.	Vol.
Nitrogen	1	14	82.35	1
Hydrogen	3	3	17.65	3
Ammonia	1	17	100	2

At a red heat it is decomposed, 2 vols. becoming 4, viz., 3 of hydrogen, and 1 of nitrogen.

(45.) Ammonia turns turmeric paper brown, as potash and soda do; it is a powerful *base*—that is, acids combine with it to form *neutral salts*. If nitric acid be gradually added to a solution of ammonia, the pungency of the ammonia and the acidity of the nitric acid mutually destroy each other, and the resulting liquid tastes bitter and saline; on setting it aside, in a warm place, crystals collect in the liquid, which are nitrate of ammonia, the substance previously mentioned as a source of nitrous oxide. All other acids are (with one or two exceptions, where decomposition takes place) capable of neutralizing ammonia, forming compounds with it, of saline bitter taste, which are, for the most part, soluble in water.

(46.) The student will notice that salts are called after the acid and base, if the acid ends in *ous* the name of the salt contains the syllable *ite*; if in *ic*, *ate*, thus—hyponitr*ous* acid and ammonia form hyponitr*ite* of ammonia; nitr*ic* acid and ammonia, nitr*ate* of ammonia. Long and hard, therefore, as the chemical names appear, they are really easy and short, for they are all formed by rules, admitting very few exceptions, and give us a great deal of information. (The student is referred, for further information on chemical nomenclature and symbols, to Chap. III.)

All combinations of an acid with a base (there are other bases beside ammonia) are called salts. For example: Epsom salts are a compound of sulphuric acid and magnesia, called therefore sulphate of magnesia. The student will bear in mind that ammonia is a curious exception to the generality of bases which are oxides of metals.

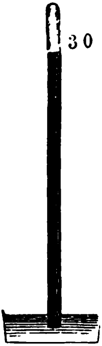
(47.) Ammonia cannot be formed by the direct union of its elements. Hydrogen and nitrogen combine to form ammonia only when they are presented to each other in the *nascent* state, as it is called: that is, when one of them is in the act of being given off from another combination. Thus, for example, on heating flesh, or wool, or bones, in close vessels, all of which contain both hydrogen and nitrogen, ammonia is formed. Fragments of stag-horns were originally employed as a source of ammonia; hence the solution got the name of hartshorn. In the violent action of dilute nitric acid on metals, ammonia is sometimes generated.

(48.) Almost the whole of the ammonia sold in this country is obtained from the refuse liquors of the gas-works. There is a small quantity of nitrogen in coal, which united with hydrogen escapes with the gas as ammonia, and is absorbed by the water through which the gas is passed, to purify it. This liquor, which from other products is excessively nauseous and disgusting, known by the name of "Blue Billy," is neutralized with sulphuric or muriatic acids; and the salts thus formed are purified by proper methods. Sulphate of ammonia is a very useful manure, and is extensively manufactured.

ATMOSPHERIC AIR.

(49.) Now that we have become acquainted with the components of our atmosphere, it will be well to examine its constitution more in detail.

We have already found that air is a mixture of oxygen and nitrogen, and have assumed the fact that it has weight. This, though generally known now, was not known in 1643. Galileo suspected the air to have weight; his pupil Torricelli afterwards demonstrated the fact. It is related that a well-digger at Florence having dug a well of more than 33 feet deep, attempted to raise water from it by a common pump. The water, however, would not rise to more than about 32 feet. It appeared to Torricelli that the cause of its rising to no more than 32 feet, might be that the weight of the air might only be sufficient to press it up to that height. He argued that if this were the case, that it would press up a heavier liquid to a less height: and, accordingly, for this purpose he used mercury, which being 13 times as heavy as water, would only rise not quite as many inches as the water had done feet. He found, as he expected, that the mercury could only be raised 30 inches, by the best made pump. He then filled a tube, about three feet long, with quicksilver, and, stopping the open end with his finger, placed it in a cistern of quicksilver. The quicksilver immediately fell, till it stood about 29 to 30 inches, according to the state of the weather, above the level of that in the basin. This instrument is in common use, and is called a barometer. The cistern is usually concealed, and a scale of inches is applied to the tube, to mark the height at which the quicksilver stands. When the instrument is to be merely used as a weather-glass, only the inches 31, 30, 28, are numbered, as the mercury never falls below, or rises above these limits. It is well known that a fall in the quicksilver presages rain. (This instrument is minutely described in Moseley's "Treatise," to which the reader is referred.) The pressure of the atmosphere is well shown, by placing the hand upon an open top receiver, and exhausting the air beneath when the pressure is felt; it amounts to about 14 pounds on the square inch.



(50.) Composition of the Atmosphere.—By experiment, it is found that the composition of the atmosphere is extremely uniform in all parts of the world; it consists of—

	Measure.	Weight.
Oxygen	208	230
Nitrogen	792	770
	1000	1000

Beside these there are minute and variable quantities of other substances, of which carbonic acid and aqueous vapour are the most important. The proportion of carbonic acid is about from 3 to 6 parts in 10,000. It serves as the food of plants, which absorb the greater portion of their charcoal from the air, in the form of carbonic acid, evolving oxygen. Aqueous vapour, or dampness, is also present: this is the cause why many substances become damp spontaneously, having a greater attraction for moisture than the air. Every housewife knows that linen has this property; it is possessed, in a still more eminent degree, by certain salts, which absorb so much as absolutely to become liquid: such salts are said to be deliquescent. The aqueous vapour dissolved in the air increases with the temperature; hence, if a cold body is brought into a warm room, charged with moisture, the vapour is precipitated on it in the form of dew. This is to be observed in cold wine brought up into a warm dining room. Besides these substances, there is a trace of carbonate of ammonia, and oftentimes of other substances. Carbonate of ammonia, according to the experiments of Liebig, serves also as food for plants.

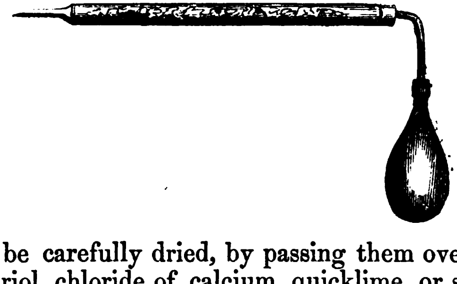
(51.) The specific gravity of common air is usually considered as 1.000, it being taken as the standard to which all other gases are referred. Air is so much lighter than water, that a reference to water as the standard would be inconvenient. The numbers would contain too many ciphers.

(52.) In order to give the student an idea of the different specific gravities of different substances, we have here taken three bodies in each of the different states of gas or vapour, liquid, and solid. The substances we have chosen are respectively the lightest, the heaviest, and an intermediate substance of common occurrence, in each class.

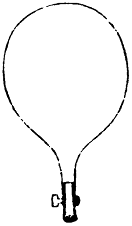
TABLE III.

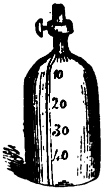
Name.	Symbol.	Weight of 100 Cubic Inches. Grains.	Specific Gravity Air 1.	Specific Gravity Water 1.
Hydrogen	H	2.138	0.0694	0.0000846
Air		31.000	1.0000	0.0012277
Vapour of Iodide of Arsenic	$As I^3$	499.100	16.1000	0.0197659
Etherine	$C^4 H^4$	15831.750	510.378	0.627
Water	$H O$	25250.000	814.000	1.000
Mercury	Hg	340875.000	10989.000	13.559
Potassium	K	21847.250	704.110	0.865
Silver	Ag	262600.000	8468.600	10.420
Platinum	Pl	542875.000	17512.000	21.500

(53.) *Determination of specific gravity of Gases.* A good air-pump must be provided, and the gases must be carefully dried, by passing them over oil of vitriol, chloride of calcium, quicklime, or some other substance having a powerful attraction for water; for this purpose, the substance used to dry the gas may be put in fragments into a long tube, and the gas passed slowly over it; it must then



be collected over quicksilver. A flask must be provided of known weight, with a very light stop-cock cemented into its mouth; this is screwed into the plate of the air-pump, and carefully exhausted of air; it is then to be weighed; a graduated jar standing over quicksilver, contains the gas; the flask is screwed off the air-pump, (the stop-cock being previously turned off,) and screwed on to the top of the air-jar. Both cocks are then carefully opened, and the gas rushes into the flask; this is then carefully weighed again, and the increase of weight is manifestly the weight of the gas introduced. As gases expand considerably by heat, care must be taken that the temperature be the same throughout. Also, since when the barometer is high, the air is heavier than when it is low, this circumstance must also be taken into account. When not otherwise stated, the temperature of the gas is supposed to be 60°, and the barometer to stand at 30 inches; should this not be the case, a correction must be made by calculations, into which we cannot enter here.





CARBON.—C 6.

(54.) This element is already familiar in the form of charcoal; its purest form, however, is the diamond, which is nearly pure carbon. It is incombustible in this state, under ordinary circumstances, but if it be intensely heated by the oxyhydrogen blow-pipe, it burns into carbonic acid when plunged into oxygen gas, with exactly the same appearance and results as a piece of hard burnt charcoal. Plumbago, graphite, or black lead as it is commonly called, are also forms of carbon, more or less mixed with iron. So also are several kinds of coal which burn without smoke, and coke. Carbon is totally infusible; when exposed to an intense heat, it becomes harder and denser, but is altered in no other respect. The diamond (and some of the harder forms of charcoal also, it is said), may be used to cut glass.

(55.) Carbon and oxygen combine in three proportions; one of these (oxalic acid) is peculiar to the organic kingdom, and does not therefore come within the range of this treatise, which only treats of inorganic chemistry.

Carbonic Oxide, Oxide of Carbon. CO. 14. —Carbonic oxide may be obtained, by passing carbonic acid over iron turnings in a red-hot tube;* or, by gently heating sulphuric acid with oxalic acid, passing the resulting gases through milk of lime, and collecting the portion which is not absorbed. The best method is to heat 1 part of powdered ferrocyanide of potassium with 10 of concentrated sulphuric acid, when abundance of very pure carbonic oxide is disengaged, and may be collected over water.

Carbonic oxide, is a colourless, tasteless gas, with scarcely any odour; it is very poisonous; when mixed with air and respired it produces giddiness and fainting. Its specific gravity is 0.9706; and 100 cubic inches weigh 29.0979 grains. It extinguishes flame; but burns with a pale blue light, which seems to be the cause of the blue lambent flames seen to play over coke or cinder fires. The result of its combustion, is carbonic acid only. Its symbol is CO. It consists of—

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* $CO^2 + Fe = FeO + CO$.

	Atoms.	Weight.	per Cent.
Carbon	1	6	42.86
Oxygen	1	8	57.14
Carbonic Oxide . .	1	14	100

It has neither basic nor acid properties.

(56.) Carbonic Acid. CO^2. 22.—This compound was originally termed fixed air, because it exists *fixed* in chalk; and the most expeditious and economical method of preparing it, is by pouring some dilute muriatic acid on fragments of marble, when the gas is abundantly given off, and may be collected over tepid water. It, as we have already noticed, is colourless, of a slightly sour odour and taste. Specific gravity, 1.52; 100 cubic inches weigh 47.2 grains. It cannot be breathed; for if the attempt be made with the pure gas, the throat closes itself against it with a sort of spasm; when breathed much diluted, it produces drowsiness and insensibility; in very minute quantities, it is not deleterious, being absolutely produced in the lungs, and respired at every breath. It is often found at the bottom of wells and pits, and persons have been suffocated by breathing it. Should any one have fainted under its influence, the best means of recovery are, dashing cold water upon the body, and stimulants applied externally to the chest and extremities—a mustard plaster, for example; if the body be cold, a warm bath should be used. Porter, ale, cider, champagne, &c., owe their briskness to this gas; which, though poisonous to the lungs, is not deleterious (at least in moderate quantities) to the stomach. It consists of—

	Atoms.	Weight.	per Cent.
Carbon	1	6	27.27
Oxygen	2	16	72.73
Carbonic Acid . . .	1	22	100

(57.) Carbonic acid gas, under considerable pressure and a low temperature, is reduced into a liquid; it is then clear, colourless, and very limpid. If allowed to escape in a jet against the bulb of a spirit thermometer tube, the spirit sinks to 130° below 0. Mercury is rapidly frozen; if the jet be allowed to escape into a vial, the liquid carbonic acid freezes by the cold produced by its own evaporation. In this state it may be held in the hand, and looks like snow. Though very cold it does not feel so, as the carbonic acid gas escaping from it, prevents it touching the skin; if pressed into it forcibly, it causes a burning sensation. In fact, so similar are the sensations of intense heat and intense cold, that a person ignorant of the low temperature of frozen mercury, would declare that it was burning hot. With the cold produced by carbonic acid, Faraday succeeded in freezing nitrous oxide. The pressure necessary to condense those gases which are condensible into a liquid, is given in Table II. Col. IV. contains the pressure; Col. V. the temperature; Col. VI. those gases which have been frozen.

(58.) Carbonic acid is a weak acid, neutralizing the stronger bases imperfectly, and easily displaced by other acids. Chalk is an instance of a carbonate, being a carbonate of lime. Carbonate of soda is also well known, and the effervescence on adding tartaric acid to its solution, is due to the escape of carbonic acid. Smelling salts are a sesquicarbonate of ammonia.

(59.) COMPOUNDS OF CARBON AND HYDROGEN.—These are very numerous, and are mostly, perhaps entirely, of organic origin. They cannot be formed by the direct union of their elements, but always arise from the decomposition of vegetable or animal bodies.

LIGHT CARBURETTED HYDROGEN, MARSH GAS, FIRE DAMP, GAS OF THE ACETATES. CH^2. 8.—This gas is the principal portion of the fire-damp of coal mines, from which such fearful accidents frequently happen; it issues for a long time and with great force from holes in the coal seams, called by the miners, blowers. It may also be obtained by stirring stagnant pools, in which water plants grow; the bubbles, as they rise, may be set on fire, or collected in an inverted jar full of water. The best method of preparing it, is to mix 40 parts of crystallized acetate of soda, 40 solid hydrate of potash, and 60 quicklime; on heating, the gas comes over nearly pure, and may be collected over water. It is colourless, and nearly inodorous; combustible, burning into carbonic acid and water. It is not poisonous, and may be breathed without injury. Its specific gravity is .589; 100 cubic inches weigh 17.41 grains. It is composed of,

	Atoms.	Weight.	per Cent.
Carbon	1	6	75
Hydrogen	2	2	25
Carburetted Hydrogen .	1	8	100

It explodes when mixed with twice its bulk of oxygen, and nothing remains but carbonic acid and water. Mixed with *less* than 4 measures of air, the gas *burns*, *explodes* with between 4 and 18 measures: a candle *burns* in it with *enlarged flame*, when there is more than 18 measures of air to 1 of gas.

(60.) OLEFIANT GAS, CARBURET OF HYDROGEN, BIHYDROCARBON, C^2H^2. 14, is usually obtained by the decomposition of alcohol by sulphuric acid; 2 of acid and 1 of strong spirits of wine, should be put into a flask; on heating the flask, olefiant gas goes over, which should be washed with lime water to free it from a little acid, and collected over water. Olefiant gas is colourless, with a slight odour of garlic; very combustible, burning with a brilliant light. It extinguishes flame, and is not respirable. 100 cubic inches weigh 30.57 grs.; its specific gravity is .981. It explodes violently when mixed with air, and especially with oxygen, carbonic acid and water being the result. By using 3 volumes of oxygen, the gas is entirely consumed. And it thus appears that it contains

	Atoms.	Weight.	per Cent.
Carbon	2	12	85.7
Hydrogen	2	2	14.3
Olefiant Gas	1	14	100

When one volume of chlorine and two of olefiant gas are mixed in a clean glass globe, they act slowly on each other, and an oily fluid is formed; the olefiant gas should be rather in excess, and the resulting liquid should be washed and distilled off chloride of calcium. Its composition is $C^2 H^2 Cl$. It has been used to produce insensibility to pain in the same manner as, but is less dangerous than, chloroform. It is from this oil the gas has derived its name; olefiant means oil-forming.

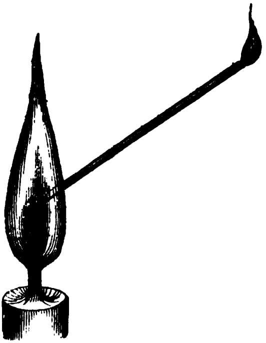
(61.) COAL GAS is a mixture of the two preceding substances, with others in variable proportions. It is obtained by exposing coal to a full red heat, in a close cast-iron vessel, called a retort. The impure gas is conducted, first of all, into a large horizontal pipe half full of water, by a pipe from the retort, which dips below the surface of the liquid; it is next passed through a series of pipes, over which cold water trickles—here vapours of tar and other substances condense; it is then passed through lime in vessels called purifiers,—these are made of iron, and filled with slack lime and water to about the thickness of milk; the gas is admitted through a number of small holes at the bottom, and the liquid is constantly stirred by a rouser; last of all, it is preserved for use in large iron gas holders, from which it passes through the mains to the consumers. The following are the usual constituents of coal gas:—

Light Carburetted Hydrogen.
Olefiant Gas.
Hydrogen.
Carbonic Oxide.
Nitrogen.
Vapour of liquid compounds of Carbon and Hydrogen.
Vapour of Bisulphuret of Carbon.

CONDENSED IN THE PURIFIERS.

Tar and Volatile Oils.
Sulphate and other Salts of Ammonia.
Sulphuretted Hydrogen.
Carbonic Acid.
Cyanogen, or Sulphocyanogen.

(62.) COMBUSTION.—When a solid body is heated beyond a certain temperature it emits light; at about 1,000° it becomes dull red; then, as it gets hotter, red; then cherry-red, and lastly white; when the heat is very great, the light becomes exceedingly powerful, and acquires a tint of violet. Bodies in this state are said to be incandescent. In whatever way the body is heated, it makes no difference in this respect; any cause which raises its temperature to a sufficient extent, (as chemical action, the heat of the sun concentrated by a burning-glass, or electricity from a galvanic battery,) produces the same effect. Gases do not become luminous, however, until very intensely heated, and then but feebly so; hence a burning jet of hydrogen, though very hot, gives very little light, as gases are burned and no solid matter produced; while a platinum wire held in the flame becomes white-hot, and emits a most brilliant light. If we sift fine sand, or dust some lime into the flame, its luminousness is greatly increased, as the minute particles of incombustible substance become white-hot. This is in truth what really takes place in all highly luminous flames. There are in all such, minute particles of solid matter, which being white-hot emit an intense light; and in our ordinary gas and oil flames these are minute particles of soot or fine charcoal; a flame is therefore a *shower of brilliant sparks.* If we examine a candle we shall find the flame is distinctly composed of three parts: the outside, which burns with a pale blue light; within that a brilliant cone of light; and in the centre a core of combustible gases. This may be observed by putting a card into the candle, when only a ring of black will be formed; if a piece of fine wire gauze be used, this ring may be seen on looking down into the flame. If a glass tube be placed in the core of the flame, the heated gases may be burned at the other end, as in the figure. The reason of the deposition of solid particles of carbon in the flame is, that hydrogen being more combustible than carbon, burns first, and precipitates the carbon in



soot, which of course becomes white-hot and then burns also. If so much air were supplied to the flame as to consume both carbon and hydrogen at once, the flame would become much hotter, but would give scarcely any light, (a gas flame blown by the wind burns blue for this reason). Under ordinary circumstances only just the outside of the flame is exposed to the air; hence the oxygen being insufficient to combine with both the hydrogen and carbon at once, they are, so to speak, burned separately.

(63.) If we introduce air into the centre of the flame, of course the whole will be burned at once; the inner part by the air from the blast, and the outer by that with which it is in contact. The heat produced is very great. The flame will be observed to consist of two cones. The space between them is filled with combustible matter, having a great affinity for oxygen; and therefore possessing powerful deoxidizing, or reducing powers; the air beyond the cone, on the contrary, oxidizes with great facility. The mouth blow-pipe is a very useful instrument to the chemical student. The method of using it is explained in the chapter on Manipulation.

(64.) We have before observed that light carburetted hydrogen collects in coal mines; and great damage is sometimes done by its accidental explosion, when a lighted candle is brought into a mixture of it with air. Providentially, however, it is not only more respirable than other gases are generally found to be, but requires a higher temperature to set it on fire; circumstances of no small moment, when we consider the value of coal to the civilized world, and the importance it is to have it cheap. Thus while hydrogen is inflamed by a red-hot wire, it requires a white heat to inflame carburetted hydrogen; nor will these gases burn below this temperature. This may be observed by holding a piece of wire gauze over a gas flame. The gas will pass through it unburned; and if the gauze be sufficiently thick to conduct the heat away, so that its temperature shall not rise to bright redness, the gas will not take fire. Sir Humphry Davy took advantage of this circumstance in the construction of his safety-lamp; which is nothing more than an ordinary lamp surrounded with gauze, which for greater security is made double. If this lamp be taken into the gallery of a mine charged with fire-damp, the flame is observed gradually to elongate, and if the atmosphere be very impure, will be extinguished altogether, while the gas itself will burn within the gauze; if the air be still, this may heat the gauze to redness, but no higher. On bringing the lamp into a purer atmosphere the wick is rekindled. In a strong current of gas mixed with air the wire sometimes becomes heated to whiteness, when an explosion ensues. This lamp is appropriately called "a Davy;" and with it, when carefully used, an accident cannot happen. Unfortunately, the miners generally are not cautious; and one careless person may be the means of the loss of many lives. In the case of an explosion, however, the carbonic acid produced does more harm than the fire. This is well known to the miners, who say that it is the after-damp or choke-damp which is so destructive.

(65.) The principle of the Davy lamp may be made use of in the laboratory, for the combustion of gas, to heat retorts, flasks, &c. A copper chimney, with a piece of gauze at the top, is put over an ordinary gas jet; the gas is turned on, and the mixture of gas and air fired above the gauze, when it burns with a blue flame and much heat; it has the advantage also, that it does not smoke the bottom of the flasks.

The same principle is used in Heming's jet. This is a brass pipe of four inches long, which is filled with thin brass wires, and a rod of brass driven into the centre, wedging them tight; and thus forming a series of very fine metal tubes, their cooling power is so great that a jet being screwed on, a mixture of oxygen and hydrogen may be fired in safety at the jet. Nevertheless it is desirable to avoid mixing the gases, for just the same reason as it is not prudent to keep a large quantity of gunpowder, even when carefully locked-up.

(66.) **Carbon** and **Nitrogen** also unite and form several compounds, which are remarkable for behaving like elements. The consideration of these will be deferred till we come to treat of the radicle cyanogen, which is one of them.

SULPHUR.—S 16.

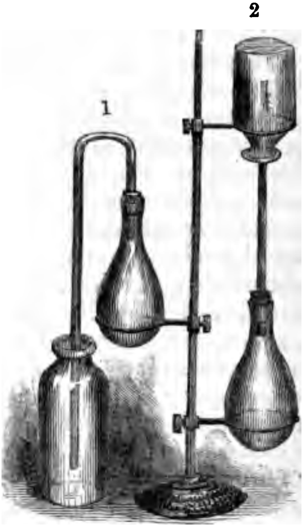
(67.) This is also an element with which the student is already acquainted. Its commonest form is in rolls; it is then called roll-sulphur, or brimstone. It is constantly found native; the island of Sicily furnishes it in great abundance, many thousand tons being imported thence into England every year. Pure sulphur is a pale yellow solid. Specific gravity is 1.98. It melts at 232°; gets thick again at 320°, and is then of a red tint; at 430° it will not pour out of the vessel; at 480° it is fluid again; boils at 600°; distilling unchanged, if air be excluded. It condenses in the form of a yellow crystalline powder, known as flowers of sulphur. Its vapour is remarkably heavy; specific gravity, 6.654, or not quite seven times as heavy as air. It does not dissolve in water or spirits, but is soluble in oil of turpentine and fat oils, and very considerably so in bisulphuret of carbon. Out of this solution it crystallizes in octohedra, with a rhombic base. When cooled from the melted state it crystallizes in long prisms; it is hence said to be *dimorphous,* from the Greek, which means *double formed.*

SULPHUR AND OXYGEN.

(68.) No less than eight different compounds of sulphur with oxygen are known; only two of which are of any great importance, namely, the sulphurous and sulphuric acid.

(69.) Sulphurous Acid. SO^2 32.—When sulphur is burned in dry air, nothing is produced but sulphurous acid. The most available method of preparing it is, however, by the action of sulphuric acid on copper-clippings; these may be put into a flask with oil of vitriol and heated; a part of the acid is decomposed, being converted into sulphurous acid by loss of oxygen, which is transferred to the metal, the oxide of which forms a base to the sulphuric acid; sulphurous acid escapes, and when the process is over, sulphate of de of copper, or blue vitriol, crystallizes ;he liquor.

hurous acid is a colourless gas, having the r odour of burning brimstone; it instantly ishes flame, and when breathed, even in iall quantity, produces a painful sensation ession at the chest. Its specific gravity is One hundred cubic inches weigh 68.36 grs. ermanent gas at common temperatures, but assed through a tube cooled to 0°, it con- into a colourless limpid liquid. It is rapidly d by water, which condenses 30 times its ; it can there- only collected uicksilver, in curial trough; re this costly us is not at by displace- s in fig. 1. A iter than air, ımmonia, may cted, as in fig. but little con- ed with com- . Its solution r can be kept ;ed for any of time if air resent; other- is gradually ed, by absorp- oxygen, into sulphuric acid. The sul- acid and oxygen will not act on each both be perfectly dry.

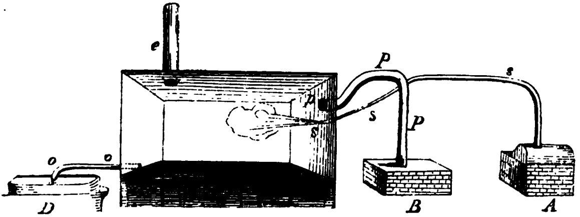


Sulphurous acid consists of—

	Atoms.	Weight.	per Cent.	Vol.
Sulphur	1	16	50	$\frac{1}{6}$
Oxygen	2	16	50	1
	—	—	——	—
Sulphurous Acid .	1	32	100	1

This is proved by burning sulphur in dry oxygen, and weighing the gas, and its symbol is SO^2. It has bleaching properties, and is used in the arts to whiten straw for bonnets, and woollen goods. A piece of blue litmus introduced into it is first reddened, and then bleached. A stronger acid will often restore the colour. Sulphurous acid forms salts with bases, which are, of course, termed sulphites; they are of little importance.

(70.) Sulphuric Acid, Oil of Vitriol. SO^3.—This important acid was originally obtained by the distillation of green vitriol, or sulphate of iron; an oily intensely sour liquid rises at a bright red heat, which was called, therefore, *oil* of *vitriol*. It is prepared in this country almost exclusively by burning sulphur and nitre together; and passing the mixed sulphurous and nitrous acid into a chamber generally made of lead, containing air, steam, and a small quantity of water, when a reaction takes place, by which sulphurous acid becomes converted into sulphuric acid. The mode of preparing it on a great scale, is as follows:—A is a steam boiler, of the usual construction; B is a kind of low brick oven, with means of making a fire underneath; in this the sulphur is placed, and is kindled by heating the oven from below. At the back of B is an iron pot, containing nitre, or nitrate of soda; this is decomposed by the heat, and sulphurous acid and nitrous gases escape up the pipe P P into a large leaden chamber C, steam from the boiler A is conducted by the pipe s s, so as continually to keep a jet of steam playing into the chamber; advantage is taken, too, of the entering jet to blow air into the chamber. The sulphuric acid produced is absorbed by water previously introduced at the bottom of the chamber, which gradually becomes more and more sour. There is an overflow pipe fixed at the proper height in the chamber, which always keeps the acid water at one level, the condensed steam supplying the requisite amount of fresh water; o o is this overflow pipe, which conducts the acid into a leaden evaporating pan D, where it is boiled till it attains a specific gravity of 1.70; if it be required more highly concentrated, it is run into stills of platinum, set in cast iron; here it is boiled down till it attains a specific gravity of 1.84; it is then run off through a platinum worm to cool it, and stored up in large bottles, protected by basket-work, called carboys. The spent gases escape by the pipe *e*; when the process is well conducted, these consist almost entirely of nitrogen, with a mere trace of sulphurous acid and some nitric oxide.



(71.) Sulphuric acid, as thus obtained, is a dense oily liquid, specific gravity 1.84, of an intensely sour taste, even when largely diluted with water, and powerfully reddening vegetable blues. It boils at

620°, or a heat nearly approaching to redness. It freezes at 15° below 0°.* In this state it contains 9 parts of water to 40 dry sulphurous acid, or 81 per cent. of real acid; oil of vitriol is a definite combination, consisting of one equivalent of water to one of acid, or a protohydrate of sulphuric acid. Its symbol is $SO^3 + HO$.

Concentrated oil of vitriol causes great heat when mixed with water: if 73 parts of strong acid be mixed with 27 of water, the temperature rises considerably above the boiling point of water. The student is therefore cautioned against making this mixture in thick glass vessels, as they are almost sure to be broken by the heat.

(72.) DRY SULPHURIC ACID, ANHYDROUS ACID. SO^3.—At Nordhausen, in Germany, sulphuric acid is distilled from green vitriol. For this purpose. protosulphate of iron, deprived of its water of crystallization, is distilled in a coated earthen retort, at a bright red heat, a brown caustic liquor distils over, which smokes when exposed to the air, from the escape of highly volatile dry sulphuric acid; the brown liquid is put into a retort, and carefully distilled, at a low temperature, when the dry acid passes over in drops, which concrete into a silky-looking mass of crystals; this is dry sulphuric acid. The attraction of the anhydrous acid for water is so great that, dropped into that liquid, it produces a hissing noise, and great heat; if mixed with just sufficient water to convert it into hydrate, it combines with the evolution of heat and light; passed through a red hot tube, it is resolved into one volume of oxygen, and two of sulphurous acid. It therefore consists of—

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* Degrees below 0° are distinguished by putting the sign (−), read *minus*, before them, as −15°.

	Atoms.	Weight.	per Cent.
Sulphur	1	16	40
Oxygen	3	24	60
Sulphuric Acid . .	1	40	100

and its symbol is SO^3.

(73.) THEORY OF THE CHAMBER PROCESS.—It is found by experiment, and confirmed by calculation, that air is necessary to the success of this process, and means are taken to introduce it into the chamber. What, then, is the use of the nitrous acid vapour which is introduced with the sulphurous acid formed by the combustion of the sulphur? When the vapours of sulphurous acid and nitrous acid are perfectly dry, they do not act upon each other: in the presence of moisture, however, they unite and form a white crystalline solid; this, on the further addition of water, is decomposed, and becomes sulphuric acid and nitric oxide, which latter, escaping from the liquid in the form of gas, instantly becomes nitrous acid by contact of air; this unites with a fresh proportion of sulphurous acid, and is again decomposed. Hence, then, we see the great advantage of the jet of steam playing into the chambers. The nitrous acid acts as a *carrier*, taking the oxygen from the atmosphere to the sulphurous acid. The advanced student will be glad to see the above process in symbols, thus:—

Gases introduced into the chamber, are—

$$SO^2 \text{ and } NO^4 \text{ with vapour of } HO;$$

the white solid is

$$2SO^2 + NO^4;$$

the presence of water converts this into

$$2SO^2 + NO^4 + 2HO;$$

Equal to $2(SO^3 HO) + NO^2$;

or two equivalents of sulphuric acid remain, and NO^2 becomes NO^4 by absorbing oxygen. It is perhaps, however, too much to say, that this is exactly the reaction which does take place in the chamber, as there are several which may all probably result in the ultimate formation of sulphuric acid.

(74.) Sulphuric acid expels almost all other acids from their combinations; hence its extensive use in chemical manufactures. Some of its salts are in great demand, and well known. Plaster of Paris is sulphate of lime; Epsom salt, sulphate of magnesia; glauber salt is sulphate of soda. Many tons of acid are prepared annually in Great Britain at a price of 1*d.* to 1¼*d.* per lb. wholesale.

(75.) HYPO-SULPHUROUS ACID. S^2O^2.—This is formed by digesting sulphur in a solution of sulphate of soda, or potash; crystals of hypo-sulphite of soda, or potash, are formed on evaporation. If we attempt, however, to displace this acid, it spontaneously decomposes into sulphur and sulphurous acid. Hypo-sulphite of soda is extensively used in the new process of photogenic drawing.

HYPO-SULPHURIC ACID. S^2O^5.—This is prepared by passing sulphurous acid through ice-cold water in which peroxide of manganese is suspended. Hypo-sulphate of manganese is formed; this is decomposed with pure baryta, and this again with sulphuric acid. The resulting solution of hypo-sulphuric acid may be evaporated under an air pump till it acquires a specific gravity, 1.347; if its further concentration be attempted, it decomposes into sulphurous acid and sulphur.

(76.) SULPHURETTED HYPO-SULPHURIC ACID, S^3O^5, and BI-SULPHURETTED HYPO-SULPHURIC *ACIDS*, S^4O^5, contain, respectively, one and two equivalents of sulphur more than the hypo-sulphurous, which they much resemble.

(77.) Two new acids have also been discovered, resulting from the decomposition of chloride of sulphur.

(78.) SULPHURETTED HYDROGEN. HS.—Sulphur and hydrogen unite to form an acid; these substances do not combine, however, except when presented to each other in the nascent state. Proto-sulphuret of iron may be put into the hydrogen apparatus, and dilute acid poured on it; when sulphuretted hydrogen passes over, and may be collected over warm water; cold water absorbs rather more than its own bulk of the gas.

Sulphuretted hydrogen is a colourless gas, of a most nauseous odour, resembling that of rotten eggs, or a very foul sewer, (both of which, in fact, owe their odour to its presence;) 100 cubic inches weigh 36.5 grains, specific gravity 1.786; it is inflammable, and if burned with limited access of air, sulphur is deposited; its complete combustion produces sulphurous acid and water; it extinguishes the flame of a taper. It is totally unrespirable, and is very deleterious, even when largely diluted with air, producing sickness and fainting. The best method is to sprinkle the contaminated room with solution of chloride of lime, as chlorine instantly decomposes sulphuretted hydrogen. It feebly reddens litmus, and neutralizes bases, a sulphuret of the metal of the base, and the formation of water being the result; thus, M standing for a metal, $HS + MO$ becomes $HO + MS$. There are several other acids formed by the union of hydrogen with the non-metallic elements, which are hence called hydracids. They all consist of one equivalent of hydrogen with an equivalent of the element, and neutralize bases in a manner corresponding to that explained above.

Sulphuretted hydrogen consists of—

	Atoms.	Weight.	per Cent.	Vol.
Sulphur	1	16	94.1	$\frac{1}{6}$
Hydrogen	1	1	5.9	1
Sulphuretted Hydrogen	1	17	100.0	1

PERSULPHURET OF HYDROGEN, HS^2, is formed by dropping solution of persulphuret of potassium into dilute muriatic acid; if the acid be dropped in with the salt, sulphur is thrown down, and sulphuretted hydrogen formed. It is a yellow liquid; specific gravity, 1.7; of an irritating odour; it bleaches, and is decomposed by the mere contact of metals, so that it resembles peroxide of hydrogen.

(79.) SULPHUR AND CARBON. BISULPHURET OF CARBON. CS^2.—This compound may be prepared by passing vapour of sulphur over red-hot charcoal in a porcelain tube; it must be received into a flask, surrounded by water, as cold as can be procured; it may be purified by rectification off chloride of calcium. It is a very volatile and inflammable colourless liquid, of a pungent taste, and peculiar fetid odour. Its specific gravity is 1.272; it boils at 106°, and does not freeze at — 60°. It dissolves sulphur and India-rubber. It has not yet been applied to any important use, except in the process of vulcanizing India-rubber.

(80.) SULPHURET OF NITROGEN, NS^3, is formed by the action of water on the ammonia chloride of sulphur. Sulphuret of nitrogen precipitates in the form of a greenish yellow powder; it consists of NS^3.

SELENIUM.—Se 30.

(81.) Selenium is a rare substance, found in some of the ores of the Hartz mountains, and in the pyrites of Anglesea, replacing sulphur, to which it bears a strong resemblance. It is a solid, of a dark colour, and dim metallic lustre; its specific gravity is 4.32. It softens by heat, being viscid at 212°, and fluid a little above; at 650 it boils with a yellow vapour. It is very rare, and has been applied to no useful purpose. It unites with oxygen in three proportions, forming an oxide, and two acids which resemble strongly the sulphurous and sulphuric acids.

(82.) SELENIOUS OXIDE, OXIDE OF SELENIUM, SeO, is formed by heating selenium in a limited quantity of air, and washing out any acid. Its smell resembles that of decayed horse radish.

(83.) SELENIOUS ACID, SeO^2, is formed by burning selenium in oxygen. It forms long white brilliant prismatic crystals; its vapour is greenish.

(84.) SELENIC ACID, SeO^3. Selenium is fused with nitre; seleniate of potash is thus formed. This may be decomposed with nitrate of lead, and the resulting seleniate of lead by sulphuretted hydrogen. The hydrated acid resembles oil of vitriol; it does not exist independently of water.

(85.) SELENIURETTED HYDROGEN, HSe, may be prepared by a process similar to that for preparing sulphuretted hydrogen; it has a most powerful action on the organs of smelling; a single bubble will produce all the effects of a severe cold.

CHLORINE.—Cl 36.

(86.) This element, together with the next three, Iodine, Bromine, and Fluorine, form a natural group, having a very decided resemblance to each other, so much so, that a description of one would almost serve for all the rest.

Chlorine may be prepared by pouring muriatic or hydrochloric acid on peroxide of manganese in a flask, and applying a gentle heat, a heavy yellow gas is disengaged,* which may be collected over warm water; it cannot be collected over mercury, as it is absorbed by that fluid. Chlorine is called from a Greek word, signifying "yellow green."

Chlorine is a greenish yellow gas, of an intolerably suffocating odour; it is soluble in water, to the extent of twice its volume. When the solution is exposed to light, oxygen is given out, and hydrochloric acid formed. Its specific gravity is 2.47; and 100 cubic inches weigh 76.6 grains; under a pressure of four atmospheres it condenses into a limpid yellow liquid. It is of course unrespirable; and even when largely diluted with air, produces a very violent cough. Great care should be taken, therefore, not to breathe it; in case of an accident, however, sugar and water, with a little white wine, should be used as a gargle. It has powerful bleaching properties, as may be shown by holding a piece of litmus paper in the gas; and it is prepared in large quantities for this purpose. It is also a powerful disinfectant. When thus used the infected articles may be dipped into a very weak solution of chloride of lime, or exposed to the vapour of chlorine as it is gradually given off from the chloride. Care must be taken not to use an excess, as the article, if dyed with a vegetable colour, will almost infallibly be partially bleached.

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* The reaction is $2\,H\,Cl + Mn\,O^2$, becomes $Cl\,Mn + 2\,(H\,O) + Cl$.

(87.) Chlorine is used to purify the air of foul sewers and drains; it unites with the hydrogen of the deleterious gases which arise from these, and destroys their odour. This may be strikingly shown with sulphuretted hydrogen, if a bottle of chlorine, and another of sulphuretted hydrogen be placed mouth to mouth; the chlorine instantly unites with the hydrogen, forming hydrochloric acid, and sulphur is deposited in fine powder. If a room be contaminated with sulphuretted hydrogen, the best means of cure is to allow a little chlorine to escape into it. The constitution of many other of the deleterious gases which rise from putrifying animal or vegetable substances, is not well known; in many cases, however, we cannot doubt that they are acted on in a manner similar to the above.

Phosphorus and many of the metals take fire spontaneously in chlorine. A mixture of equal bulks of chlorine and hydrogen explodes by an electric spark, or a hot iron, or even by exposure to the sun's rays. Diffused daylight causes the combination of the gases silently. A candle burns in chlorine with a small red and very smoky flame; in this case only the hydrogen burns, and the whole of the carbon is deposited. If the student will look again over the Section on Combustion, he cannot fail to be struck with the very nice adjustment of affinities which is required, even in what appears so simple a thing as the burning of a candle. Had the affinity of carbon for oxygen been no greater than it is for chlorine, our candles and gas flames would have given only a dark-red and intolerably smoky flame; had it been much greater than it is, we should have had our candles burning with a hot blue flame, giving no light.

(88.) Chlorine combines with all the metals, forming chlorides; with the metal sodium it forms common salt, which is therefore chloride of sodium. All the chlorides are soluble in water, except chloride of silver and protochloride of mercury. Nitrate of silver is therefore always kept in the laboratory, as a test for chlorine in combination with metals. If a single drop of brine be put into a tumbler of water, nitrate of silver will instantly form a white cloud when poured into the solution. Most of the ordinary spring waters contain chlorides, which may be detected with nitrate of silver.

(89.) CHLORINE AND HYDROGEN. HYDROCHLORIC ACID. MURIATIC ACID. HCl. 37.—If equal measures of chlorine and hydrogen be put into a very strong tube, and an electric spark passed into the mixture, the gases combine with a violent explosion; the green colour of the chlorine disappears, the bulk or volume remaining the same, and hydrochloric acid gas is the result. It may be better prepared by pouring sulphuric acid, slightly diluted, upon common salt, and applying a gentle heat; acid fumes are abundantly given off, which appear like smoke when emitted into the air.* The gas cannot be collected over water, as it is rapidly and copiously absorbed by that liquid; the mercurial trough, or displacement, must be used.

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* $NaCl + (SO^3 + HO) = NaO, SO^3 + HCl.$

Hydrochloric acid is a colourless gas, of a sufocating odour, though much less so than chlorine. t powerfully reddens litmus paper. Its specific ravity is 1.269; 100 cubic inches weigh 39.36 rains; it is not combustible; it is very soluble n water, that fluid taking up 410 times its bulk f the gas. The solution has long been known in he arts as muriatic acid, or spirits of salt. When ure it is colourless; but as it occurs in commerce, sually has a yellowish tinge. It is used in mediine, and, mixed with nitric acid, dissolves gold; he mixture was formerly called aqua regia. It is bye product in the manufacture of soda, and is requently allowed to escape in large quantities; his should be avoided, as it is exceedingly deleerious to vegetables. It is, as we have already een, composed of equal volumes of hydrogen and hlorine united without condensation.

	Grains.
Now, 50 cubic inches of chlorine weigh . .	38.299
„ „ hydrogen „ . .	1.069
∴ 100 cubic inches of hydrochloric acid weigh	39.368

ts composition is—

	Atoms.	Weight.	per Cent.	Vol.
Hydrogen	1	1	2.7	1
Chlorine	1	36	97.3	1
Hydrochloric Acid .	1	37	100	2

(90.) Hydrochloric acid is a powerful acid, and eutralizes bases; though in this case, we are ompelled to suppose that the acid itself is deomposed, and also the oxide of the metal; for xample, if soda be neutralized with hydrochloric cid, and the solution evaporated, chloride of odium, or common salt, crystallizes. Hence we suppose that $HCl + NaO$ becomes $NaCl + HO$; the oxygen of the soda being transferred to the hydrogen of the hydrochloric acid, and the chlorine combining with the sodium. The same remark applies to all the hydro acids.

(91.) CHLORINE AND OXYGEN.—There are four compounds of chlorine and oxygen; namely,

Protoxide of chlorine, or hypochlorous acid	ClO.
Peroxide of chlorine, or chlorous acid . .	ClO^4.
Chloric acid	ClO^5.
Perchloric, or hyperchloric acid	ClO^7.

(92.) HYPOCHLOROUS ACID. ClO. 44.—This compound may be prepared by passing dry chlorine over peroxide of mercury; a yellow gas comes over, which may be collected by displacement; it is very heavy, being nearly three times as heavy as air; it smells like chlorine, and bleaches; it forms with the alkalies, bleaching salts, and exists in the disinfecting chlorides of lime and soda. It explodes when gently heated. It is absorbable by water.

(93.) CHLOROUS ACID. ClO^4. 68.—Chlorate of potash is made into a paste with cold dilute sulphuric acid, and a very gentle heat applied; a gas of much deeper colour than chlorine rises, which may be collected over quicksilver. Its smell has been compared to burnt sugar. It explodes violently when heated; two volumes of the gas expand into three, two of which are oxygen and one chlorine, whence its composition as above.

(94.) CHLORIC ACID, ClO^5, 76, may be obtained by boiling chlorate of potash with fluosilicic acid, and allowing the almost insoluble fluosilicate of potash to subside. Dry chloric acid has never been insulated; the strongest acid contains one equivalent of water, and is $ClO^5 + HO$. It neutralizes bases, forming chlorates, which all deflagrate when heated with combustible matter.

(95.) **Perchloric Acid. Hyperchloric Acid,** ClO^7, is produced by distilling perchlorate of potash, with its own weight of sulphuric acid. At 280°, white vapours rise, which condense into a liquid. It may be obtained in the solid crystalline form by redistillation with sulphuric acid; it is still not anhydrous. Dry hyperchloric acid has not been isolated. It is the most stable of the compounds of chlorine with oxygen.

(96.) **Chloride of Nitrogen,** NCl^3, is prepared by exposing nitrate or hydrochlorate of ammonia to the action of chlorine; a dense oily fluid, which sinks in drops through the solution, is the result. Specific gravity, 1.65. It is dangerously explosive, and should never be prepared but with the greatest caution. If a globule the size of a mustard seed be transferred to a glass basin, and touched with a long rod dipped in oil, it explodes with a flash of light, breaking the basin to atoms, and smashing the end of the stick as though it had been struck with a hammer. Phosphorus and oily substances cause its explosion; metals, resins and sugar do not.

(97.) **Chlorides of Carbon.**—There are three; namely,

Dichloride	C^2Cl.
Protochloride . . .	$C\ Cl$.
Perchloride	C^2Cl^3, or sesquichloride.

They are all prepared by the action of chlorine on organic compounds.

(98.) CHLORIDES OF SULPHUR.—There are two; namely,

Dichloride of sulphur, or bisulphuret of chlorine,	S^2Cl.
Chloride of sulphur	SCl.

CHLORIDE OF SULPHUR may be prepared by passing dry chlorine over sulphur, and redistilling, or rectifying, as it is termed. It is a yellowish fluid, exhaling suffocating fumes. Specific gravity, 1.60. It boils at 146°; and does not redden dry litmus paper. When water is present, it is decomposed into hydrochloric and hyposulphurous acids. It dissolves sulphur, and combines with it, forming the dichloride.

DICHLORIDE OF SULPHUR is a reddish-brown liquid. Specific gravity, 1.686. It boils at 282°. It much resembles the preceding. It has been used in the process of vulcanizing India-rubber.

IODINE.—I 126.

(99.) Is chiefly prepared at Glasgow, from kelp, which is the fused ash of the burnt seaweed of the western coast of Scotland and west of Ireland. For this purpose the kelp may be put in a basin, and the soluble portions dissolved out in warm water. This process is called lixivation. Evaporate the liquor till a pellicle of crystals forms on the top of it, and set it aside to crystallize; pour off the mother liquor, evaporate to dryness, and heat it with half its weight of sulphuric acid, with some finely powdered peroxide of manganese; apply a gentle heat to this mixture in a flask; fumes of a violet colour rise, and condense into metallic crystalline scales. This is Iodine, so called from its purple vapour, its name being derived from a Greek word signifying a violet.

Iodine is a grey or blackish powder; as it usually occurs, it a good deal resembles the scales from a smith's forge. Its specific gravity is 4.946; it smells something like chlorine; it stains the skin yellow. At 220° it fuses, and at 350° it boils, and produces characteristic violet-coloured fumes. Its vapour is very heavy; 100 cubic inches weigh 270.8 grains, and it is therefore nearly nine times as heavy as air. It forms a dark purple precipitate, with solution of starch, which is a very delicate test for iodine; a liquid containing only a 450 thousandth part of iodine is sensibly blued. It is a most valuable medicine, but must be used most cautiously, as it is very poisonous in an over dose; it exists in cod-liver oil, and most likely gives that medicine some of its peculiar virtues. Iodine combines with metals, forming iodides.

(100.) Hydriodic Acid. HI. 127.—Solution of this acid may be prepared by passing sulphuretted hydrogen through water in which iodine is suspended. The hydrogen goes from the sulphur to the iodine, hydriodic acid is formed, and sulphur is deposited; when the liquid has become colourless, it is heated, to expel the sulphuretted hydrogen, and filtered; the hydriodic acid remains in solution. It dissolves iodine; it cannot be long kept, as it spontaneously decomposes by contact with air. It may be obtained in the gaseous form by the action of water on iodide of phosphorus; it much resembles hydrochloric acid; its specific gravity is 4.4024; 100 cubic inches weigh 136 grains; by volume, it consists of equal measures of hydrogen and iodine vapour, united without condensation. Hydriodic acid has the same action on bases as hydrochloric.

(101.) There are three combinations of iodine and oxygen, viz.—

Oxide of Iodine?	
Iodic Acid	IO^5
Hyperiodic Acid	IO^7

Iodic Acid, IO^5, may be formed by heating iodine for a long time in strong nitric acid; the heat must be continued till the iodine disappears, the liquid evaporated to dryness, re-dissolved in water, and made to crystallize. The iodates much resemble the chlorates, and are decomposed by heat, forming iodides, oxygen being evolved.

Hyperiodic Acid. IO^7.—A hyperiodate of silver is prepared, which is dissolved in water, when it is spontaneously resolved into free hyperiodic acid, and an insoluble sub-periodate of silver. The acid is permanent in the air; it may be obtained in crystals; it is resolved into oxygen and iodine at a high temperature.

(102.) **Iodide of Nitrogen**, NI^3, is prepared by digesting iodine in ammonia. It is a black insoluble substance, exploding even when moist at a very low temperature, with a flash of light, and giving off violet fumes.

BROMINE.—Br 78.

(103.) May be obtained from the uncrystallizable residue obtained by evaporating sea-water. Chlorine is passed through it, and the liquid is then agitated with ether; and is then allowed to settle. The ether takes up the bromine, forming a brown solution, which rises to the surface, and may be poured off from the saline solution below; this is again agitated with solution of potash; the bromine combines with the potash, and, on settling, the ether rises to the top, and may be poured off and used again. The potash is now converted into bromide of potassium and bromate of potash, the liquid is evaporated to dryness, heated to dull redness, and the result is bromide of potassium; this must be treated as directed for the iodide, a deep orange vapour rises, condensing into a liquid which is bromine.

Bromine is a deep reddish-brown liquid, specific gravity 3.0, emitting brownish red vapours at ordinary temperatures; it boils at 116°, and freezes at 0° into a brittle white solid; it has a strong powerful odour, something like that of chlorine, but more disagreeable; whence its name, which is derived from a Greek word, meaning stinking. It is very poisonous.

(104.) HYDROBROMIC ACID, HBr, is evolved when bromide of potassium is acted on by sulphuric acid. It is colourless, sour, rapidly absorbable by water; it is similar in constitution to hydriodic acid, which it much resembles.

(105.) BROMIC ACID. BO^5.—If the mixture of bromate of potash and bromide of potassium, before spoken of, be evaporated, the bromate of potash being more insoluble, crystallizes out; this salt is then treated as directed for chlorate of potash. Bromic acid resembles chloric acid. Bromine is used in the photographic processes, and occasionally in medicine; it is of no great commercial importance.

(106.) BROMIDE OF NITROGEN, NB^3, is explosive, being a dark oily liquid, of pungent odour.

FLUORINE.—F 19.

(107.) This substance exists in fluor spar, which is a combination of it with the metal calcium, and is therefore fluoride of calcium. Its affinities are so energetic that no vessels can be found which are not acted on by this substance; and it has never been obtained in a fit state for examination.

(108.) Hydrofluoric Acid. HF. 20.—When powdered fluor spar is heated with concentrated sulphuric acid in a platinum retort, connected with a carefully cooled receiver of the same metal, a very volatile colourless liquid distils over, emitting dangerously suffocating fumes in the air; this is anhydrous hydrofluoric acid.* When hydrofluoric acid is put into water, it combines with it with violence, and a hissing noise. The concentrated acid dropped upon the skin produces dangerous ulcers; it consists of—

	Atoms.	Weight.	per Cent.
Fluorine	1	19	5
Hydrogen . . .	1	1	95
Hydrofluoric Acid.	1	20	100

Hydrofluoric acid may be used for etching on glass. For this purpose it should be diluted with six parts of water. The glass should be covered with a thin stratum of wax, and the lines to be engraved scratched through it with a graver; a ledge of wax should be left round the sides, to contain the acid, which should be poured on, and when the action is over, the wax may be removed from the surface of the glass with oil of turpentine. The lines will be found deeply corroded

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* The decomposition of fluor spar is as follows:—

$$CaF + (SO^3 + HO) = HF + CaO,\ SO^3.$$

into the glass. In this way bottles may be engraved for containing acids and caustic alkalis, paper labels being spoiled if a drop of the contained fluid happens to bubble over them. Hydrofluoric acid acts on bases like hydrochloric, and fluorides result.

SILICON.—Si 15.

(109.) Silicon is the basis of flint, and other siliceous minerals. The best method of preparing it is by the action of the metal potassium on the silicofluoride of potassium. When fluor spar, sulphuric acid, and powdered flints, are heated together in a retort, silicofluoric acid gas is produced, consisting of one equivalent of silicon, and two of fluorine. This gas is passed into a solution of potash, the resulting solution evaporated to dryness, and heated short of redness. The salt thus procured is mixed with nine-tenths of its weight of potassium, and the mixture heated in a covered crucible, violent reaction ensues, and the silicon is set free. When cold, the contents of the crucible are put into water, which dissolves out fluoride of potassium, and leaves silicon. Thus prepared, it is a brown substance destitute of lustre; heated in the air, it burns and becomes superficially converted into silica. After it has been strongly heated in a covered crucible, its properties are greatly changed; it becomes darker in colour, denser, and incombustible, even in the flame of the oxyhydrogen blowpipe.

(110.) Silica. Silicic Acid. SiO^2.—This is the only known oxide of silicon; it is very abundant; it is pure in rock crystal, and nearly pure in flint. Silica is really an acid, and a powerful one. Its insolubility prevents the display of any acid properties. When heated with bases, it forms salts; those of potassa and soda, which contain excess of base, are soluble in water. If fine sand be mixed with about three times its weight of dry carbonate of soda, and the mass fused in a platinum crucible, the resulting glassy mass will dissolve in water. If this be neutralized with hydrochloric acid, gelatinous hydrate of silica is precipitated. Except when recently precipitated, silica is not sensibly soluble in water, or in acids.

There is some doubt as to the constitution of silicic acid; several chemists have supposed it to consist of one equivalent of silicon, and two of oxygen; others of three of oxygen. On this latter view, the equivalent of silicon would be 22.5; the former view, however, has simplicity to recommend it, and it will then consist of—

	Atoms.	Weight.	per Cent.
Silicon . . .	1	15	48.39
Oxygen . . .	2	16	51.7
Silica	1	31	100.

Window glass is a silicate of soda with excess of silica.

(111.) CHLORIDE OF SILICON. Si Cl^2.—Chloride of silicon may be obtained by passing dry chlorine over a mixture of silicon and charcoal intimately mixed in fine powder, in a red hot porcelain tube. It is a colourless volatile liquid, of a suffocating odour, boiling at 122°, and is resolved by water into hydrochloric and silicic acids.

(112.) FLUORIDE OF SILICON. FLUOSILICIC ACID. SiF^2.—To obtain this gas, four parts of fluor spar, and three of powdered glass, are mixed in a retort, with five parts of oil of vitriol. The gas is evolved at once; when the action declines, it may be accelerated by a gentle heat. A colourless gas comes over, which fumes on contact with air, and is very absorbable by water, smelling very much like hydrochloric acid. It can be collected over mercury; its specific gravity is 3.6, and 100 cubic inches weigh 112 grains. It is incombustible, and extinguishes the flame of a taper. Water absorbs 260 times its volume, one-third of the silica at the same time being deposited. If the tube from which it issues be plunged under water, it is sure to be choked up by the deposited silica, an effect which may be prevented by allowing the tube to dip into a little mercury, so that the gas may bubble through that fluid into the water. The resulting solution is kept as a precipitant of potassa from its soluble salts.

The dry gas consists of—

	Atoms.	Weight.	per Cent.
Silicon	1	15	28.3
Fluorine . . .	2	38	71.7
Fluosilicic Acid .	1	53	100.

BORON.—B 11.

(113.) Borate of soda has long been imported from India in an impure state, under the name of Tincal, Pounxa, and Chrysocolla; purified it is called Borax. Native boracic acid occurs in the volcanic products of the Lipari islands. It is also prepared by a very curious process from the lagoons of Tuscany. To isolate boron, fluoboric acid is prepared, and potash neutralized with it; the borofluoride of potassium is then heated with potassium, the whole process being conducted as for preparing silicon.

Boron is a greenish-brown powder, infusible, without taste or smell: its specific gravity exceeds 2.0; heated red hot, it burns into boracic acid.

(114.) BORACIC ACID, BO^3, may be obtained by decomposing borax with half its weight of sulphuric acid; the hydrated acid separates in white scaly crystals; it has a slightly sour taste, and feebly reddens vegetable blues. It is soluble in about 25 parts of cold water, and much less at a boiling heat. When heated it loses water, and melts into a glassy transparent mass. This is quite fixed in the fire, although the hydrate cannot be evaporated without sensible loss. The acid consists of—

	Atoms.	Weight.	per Cent.
Boron	1	11	31.43
Oxygen	3	24	68.57
Boracic Acid	1	35	100.

	Atoms.	Weight.	perCent.
Boracic Acid	1	35	31.43
Water	3	27	68.57
Hydrated Acid	1	62	100.

Borax is used as a flux, and in soldering.

(115.) CHLORIDE OF BORON, BCl^3, may be prepared as chloride of silicon. It is a colourless gas, of a pungent odour, which fumes in air. Water resolves it into boracic and hydrochloric acid.

(116.) FLUORIDE OF BORON, BF^3, is obtained by heating one part of vitrified boracic acid, two of finely powdered fluor spar, and twelve of sulphuric acid. Fluoboric acid gas is colourless, of a pungent odour. Specific gravity 2.371. It reddens litmus paper; water absorbs 700 times its volume. It consists of—

	Atoms.	Weight.	per Cent.
Boron	1	11	16.17
Fluorine	3	57	83.83
Fluoboric Acid	1	68	100.

PHOSPHORUS.—P 32.

(117.) Phosphorus occurs most abundantly in the bones and urine of animals. It was discovered in 1669 by Brandt, while attempting to extract from urine a liquid capable of converting silver into gold. It is now largely prepared from bones by the following process:—Twenty pounds of burnt bones are heated with eight of sulphuric acid, diluted with eight of water, for six hours; the liquid is strained, evaporated to half its bulk, poured off from a sediment which then forms, and evaporated to dryness in a glass vessel. A white mass remains, which must be fused, yielding a glassy substance. This must be heated in a retort with charcoal, and at a high red heat phosphorus passes over. It is sufficiently purified by fusion under water; it is then allowed to cool, cut up into small pieces, put into a slightly taper glass tube, and again fused by immersing in hot water, and after cooling, the phosphorus is withdrawn in the form of a stick.

Phosphorus is colourless, or of a pale buff, semi-transparent, soft, like bee's-wax, at common temperature, but at 32° crystalline and brittle; exposed to air it smokes, (in the dark this smoke is luminous); it exhales an odour like garlic. Its specific gravity is 1.9 or 2.0. It melts at 110°; at 500° it boils; and the density of its vapour is 4.35. It is insoluble in water, and is usually kept in that liquid. It dissolves in oils and sulphuret of carbon. Kindled in air, it burns with a brilliant light and white smoke. It is so inflammable that it sometimes takes fire with the heat of the hand—an accident which once happened to the author; the burn is exceedingly painful, and difficult to heal. Its characteristic property is its luminousness in the dark; hence its name, phosphorus, which is Greek, and means light bringer, or light carrier. Very large quantities have been prepared in London since the introduction of lucifer matches. It is calculated that timber enough is used in this apparently trifling manufacture to build a large ship every year.

(118.) COMPOUNDS OF PHOSPHORUS AND OXYGEN.—These are four in number; viz.

Oxide of Phosphorus	$P^2 O$.
Hypophosphorous Acid	$P O$.
Phosphorous Acid	$P O^3$.
Phosphoric Acid	$P O^5$.

(119.) OXIDE OF PHOSPHORUS, $P^2 O$, is formed by throwing a jet of oxygen into phosphorus fused under hot water; combustion ensues, and phosphoric acid is formed, and a red powder, which is the oxide in question.

(120.) HYPOPHOSPHOROUS ACID. $P O$.—When phosphuret of barium is put into water, that liquid is decomposed, giving rise to phosphuretted hydrogen, phosphoric acid, hypophosphorous acid, and baryta. The hypophosphite of baryta is soluble, and may be separated from the phosphate, which is insoluble; sulphuric acid is added, which combines with the baryta, and sets the hypophosphorous acid free in solution. It is a powerful deoxidizing agent.

(121.) PHOSPHOROUS ACID, $P O^3$, is formed by the combustion of phosphorus in a very limited supply of air; it is then anhydrous, and presents the appearance of a white powder. The hydrated acid is prepared by adding water to chloride of phosphorus, and heating to expel hydrochloric acid. By evaporating the solution it may be obtained in deliquescent crystals. Exposed to air, it passes into phosphoric acid. When heated it is resolved into hydrated phosphoric acid and phosphuretted hydrogen.

(122.) PHOSPHORIC ACID, PO^5.—When phosphorus is burned in a copious supply of dry air, snow-like anhydrous phosphoric acid is formed. It has a very great attraction for water, equal to that of anhydrous sulphuric acid. Once in the state of hydrate it cannot be recovered.

Another method of obtaining the hydrated acid is by heating bone earth with sulphuric acid, precipitating the lime with slight excess of carbonate of ammonia, evaporating to dryness, and heating to redness in a platinum crucible; it melts into a glassy substance, which is deliquescent, and contains an equivalent of water.

(123.) Phosphoric acid is a curious instance of the same combination of the same substances producing compounds of different properties. Phosphoric acid occurs in three peculiar or isomeric conditions, which are known as

Metaphosphoric .	or *a* phosphoric acid,	*a* PO^5	Monobasic.
Pyrophosphoric .	or *b* phosphoric acid,	*b* PO^5	Bibasic.
Common phosphoric,	or *c* phosphoric acid,	*c* PO^5	Tribasic.

The first combines with one, the second with two, and the third with three equivalents of base; that is, if the first modification is neutralized with a certain quantity of soda, the second requires twice, and the third three times as much. These salts are all of them neutral, and must be considered as combinations of the base with different acids. Phosphate of lead is insoluble in all of these forms: by heating it with sulphuretted hydrogen, the first form gives protohydrate; the second deutohydrate; the third terhydrate of phosphoric acid in solution. The whole subject will be renewed when we come to treat of the theory of salts.

(124.) PHOSPHORUS AND HYDROGEN. PHOSPHURETTED HYDROGEN. HYDRURET OF PHOSPHORUS. PH^3.—There seem to be two varieties of this substance, which are isomeric; one of which is and one is not spontaneously inflammable. If phosphuret of lime be put into water, or, still better, into dilute hydrochloric acid, the gas is given off, which is spontaneously inflammable. On this account, if it is to be collected in any quantity, the air should be expelled from the retort by a stream of nitrogen. Each bubble as it rises into the air inflames, and in a still atmosphere produces a beautifully expanding ring of smoke. The gas has a most nauseous odour, (something like that of garlic,) which adheres to the clothes. The other variety is procured by heating hydrated phosphorous acid; it is not spontaneously inflammable, but may be made so by a very minute trace of nitrous acid. Its smell is less disagreeable than the above. The spontaneously inflammable phosphuretted hydrogen has been supposed to be the cause of ignis fatuus, Will-o'-the-wisps, or Jack-a-lanterns, as they are called by country people.

PHOSPHURET OF NITROGEN, PN^2, is obtained by the action of ammonia on chloride of phosphorus. Dry ammonia is admitted into a globe containing pure perchloride of phosphorus, surrounded by a cooling mixture; a white compound is formed,

must be heated in a glass tube, through
a current of carbonic acid should be passed,
mechanically to carry away any hydro-
ic acid which may be evolved. The sub-
e when excluded from the air is infusible at
l heat, not acted on by acids except very
y: it is acted on energetically when fused
hydrate of potash, ammonia being produced.
curious that so exceedingly fixed a sub-
e should be formed from two such volatile
ents. This white substance is then pure
ide of phosphorus.

25.) Chlorine and phosphorus unite in two
ortions, forming a protochloride and a per-
ide.

ROTOCHLORIDE OF PHOSPHORUS, $P\,Cl^3$, is formed
istilling a mixture of phosphorus and perchlo-
of mercury. It is a limpid colourless liquid;
ific gravity 1.45; neutral when dry, but be-
ng instantly acid on the addition of water.

26.) PERCHLORIDE OF PHOSPHORUS, $P\,Cl^5$,
be formed by burning phosphorus in dry
rine. It is a white volatile solid, rising in
ur at 200°; it is decomposed by contact of
r. There are similar compounds with iodine
bromine. The compounds of phosphorus with
on and sulphur are of no importance.

CYANOGEN.—Cy 26.

27.) BICARBURET OF NITROGEN, $N\,C^2$, is re-
kable for combining as an element. It has been
ed Cyanogen, because it generates Prussian
, cyanogen being compounded of two Greek
ds, signifying blue generator. It may be
ed by the action of nitrogen on charcoal, in

the presence of a base, when a cyanuret of the metal is formed. Those compound substances which combine as elements are called radicles.

Pure cyanogen is obtained by heating cyanide of mercury in a small retort to dull redness; a colourless gas passes over, which may be collected over mercury. This is the substance in question. A black substance remains in the retort, which appears to have the same constitution as cyanogen; it is called paracyanogen. Cyanogen is represented by the symbol Cy.

Cyanogen is a colourless gas, of a peculiar smell, resembling somewhat that of bitter almonds. It is combustible, burning with a purple flame, rose coloured in the centre. Its specific gravity is 1.82; 100 cubic inches weigh 55.5 grains; water dissolves 4½ volumes of this gas. It sustains a high temperature without decomposition. One volume of the gas, detonated with two of oxygen, yield one of nitrogen and two of carbonic acid. It consists, therefore, of

	Atoms.	Weight.	per Cent.
Carbon . . .	2	12	46.1
Nitrogen . .	1	14	53.9
Cyanogen . .	1	26	100.

(128.) CYANOGEN AND HYDROGEN. HYDROCYANIC ACID. PRUSSIC ACID. H Cy.—This may be formed by passing pure and dry sulphuretted hydrogen through a long tube containing cyanide of mercury, and condensing the product in a cooled receiver; or distil fifteen parts ferrocyanide of potassium with nine sulphuric acid and nine water. The resulting acid may be dried by chloride of calcium.

Anhydrous hydrocyanic acid is a limpid liquid, of a strong odour, resembling that of essence of bitter almonds. Its specific gravity at 64° is 0.696. It boils at 80°; it burns with a light-blue flame. It is a frightful poison, and cannot be prepared without the greatest danger to the operator; a few drops, or even a single drop, falling on the skin causes rapid death; it consists of

	Atoms.	Weight.	per Cent.	Vol.
Cyanogen . . .	1	26	96.3	$\frac{1}{2}$
Hydrogen . . .	1	1	3.7	$\frac{1}{2}$
Hydrocyanic Acid	1	27	100.	1

or of equal volumes of its elements, united without condensation. The dilute acid is used in medicine as a sedative. The acid and its solution in water are prone to spontaneous decomposition; they should be kept in a dark place.

(129.) Cyanogen and Oxygen.—There are three distinct isomeric compounds of cyanogen and oxygen. Cyanic acid, CyO, which is monobasic; fulminic acid, Cy^2O^2, which is bibasic; and cyanuric acid, Cy^3O^3, which is tribasic.

Hydrated Cyanic Acid may be obtained by subjecting hydrated cyanuric acid to a red heat, and condensing in a receiver, cooled to the freezing point. It is a liquid, but if the temperature be raised a little it concretes into *cyamelide*, a neutral indifferent substance; this change is attended with evolution of heat. It is caustic, its odour penetrating, not inflammable, and reddens litmus; mixed with water it resolves itself into bicarbonate of ammonia, hence it cannot be prepared by decomposing its salts with a stronger acid.

Fulminic Acid. Cy^2O^2.—This acid is contained in fulminating silver and mercury, which substances are fulminates of those bases. It has not been isolated, for on attempting to do so it is resolved into hydrocyanic acid and other products.

CYANURIC ACID. Cy^3O^3.—Dry *melam* is dissolved in sulphuric acid, and then 20 parts of water are added; the mixture is kept at its boiling point for several days, when the action is complete, (which may be known by the liquid ceasing to give a white precipitate with ammonia;) the liquid is evaporated and crystals formed, which are hydrated cyanuric acid, with four equivalents of water of crystallization; exposed to air, these fall into a white powder, which is hydrated cyanuric acid; it is inodorous and reddens litmus.

CYAMELIDE, the hydrate of cyanuric acid, when kept for some time, becomes hard and white, like porcelain; insoluble in water, alcohol and dilute acids: subjected to heat, it forms hydrated cyanic acid. The student will perceive by this that even the same elements may have very different properties when in combination in the same proportions.

(130.) Cyanogen combines with sulphur, and forms a radicle, which resembles an element in the way it combines.

SULPHOCYANOGEN, CyS^2, may be obtained by passing chlorine through sulphocyanide of potassium; it falls as a yellow powder; subjected to dry distillation, it yields bisulphuret of carbon, nitrogen and cyanogen; and a yellow substance remains in the retort, which is also a radicle, and called mellone. The symbol for sulphocyanogen is Csy.

MELLONE, C^6N^4, unites with potassium, forming mellonide of potassium. If this be dissolved in water, and decomposed by hydrochloric, sulphuric, or nitric acids, a white gelatinous substance falls, which is hydromellonic acid in the state of a hydrate.

(131.) SULPHOCYANOGEN AND HYDROGEN, SULPHOCYANIC ACID, HYDRO-SULPHOCYANIC ACID, CyS^2H, $CsyH$, is formed when sulphuretted hydrogen is passed through sulphocyanate of lead. It is colourless and sour, and very liable to spontaneous decomposition.

Sulphocyanogen exists in the liquor from the gas works; its characteristic is that of giving a dark-red solution, with a persalt of iron; it has not been applied to any use in the arts. The most valuable combination of cyanogen is one with iron, which will be found described under that metal.

If ammonia be saturated with hydro-sulphocyanic acid, evaporated to dryness under the air-pump, and heated, ammonia, sulphuretted hydrogen and bisulphuret of carbon volatilize, and MELAM, $C^{12}N^{11}H^9$, remains; from which cyanuric acid may be prepared.

CHAPTER III.

THEORY OF CHEMISTRY.

LAWS OF CHEMICAL COMBINATION.

(132.) THE student has by this time obtained a certain insight into the laws of chemical combinations; it will be desirable, however, to recapitulate and systematize those already known, and add others with which he is imperfectly acquainted. The following, then, are the laws of combination:

I. All chemical *compounds* are *definite* in their composition, and the proportion by weight of the elements is always the same in the same compound. For example, water invariably consists of hydrogen and oxygen in the definite proportion of 1 to 8, or per cent. 11.1 hydrogen, 88.9 oxygen.

II. When there is more than one compound of the same elements, the quantity of the elements in one compound bears a simple proportion to that which exists in the other compounds. For example, carbonic oxide consists of 6 parts carbon to 8 of oxygen; carbonic acid, of 6 parts carbon to twice 8, or 16 oxygen.

III. Each different element has a different weight, in which it combines with other elements, called its equivalent, and which always remains the same throughout all its combinations. Thus, 1 grain of hydrogen unites with 8 oxygen; 1 grain hydrogen with 16 sulphur; 16 sulphur with 8 oxygen, and so on.

IV. The equivalent of a compound is the sum of the equivalents of its elements. Thus, the equivalent of sulphuric acid is—

Equivalent of sulphur	16
Three equivalents oxygen (3 times 8)	24
Added, give sulphuric acid . . .	40

(133.) Law I. distinguishes compounds from mixtures; for example, any mixture of hydrogen and oxygen may be made; but, except they be in the proportion of 1 hydrogen to 8 oxygen by weight, on applying a light they will combine, leaving the excess of that gas which exceeds this proportion, while that portion of them which has united to form water will be found to have abstracted 1 part by weight hydrogen for 8 oxygen; if one or other of the gases be in great excess the mixture will not explode at all. Suppose, then, we mixed 1 grain of hydrogen with 9 grains of oxygen, after the explosion 1 grain of oxygen would be left. There is no such thing as a compound in any other proportion than that of the equivalents, or some multiple of one of them, as stated in Law II.

(134.) There may be, as we have already seen, many compounds of the same elements; these are, however, all equally definite. Thus, carbonic acid consists of two equivalents of oxygen and one of carbon, or 16 parts by weight oxygen and 6 carbon; or, stating the composition per cent. 27.27 carbon to 72.73 oxygen; and though we may obtain carbonic acid from burning a diamond or a piece of charcoal, or by displacing it from a carbonate, we still find its composition is the same, whatever its source, that is, 27.27 per cent. carbon and 72.73 oxygen, or in the proportion of 16 to 6. Now, if we pass carbonic acid over red-hot iron we find that it will just give up *half* its oxygen, and will be converted into carbonic oxide, which consists therefore of 8 oxygen to 6 carbon, or per cent. carbon 42.86, to oxygen 57.14; hence the oxygen in carbonic acid is double that in carbonic oxide; and the element oxygen in one compound bears to the element oxygen in the other the proportion of two to one. Since these proportions are obtained by multiplying, they are called multiple proportions.

The compounds of carbon with oxygen, therefore, stand thus:—

	Carbon.	Oxygen.		Carbon.	Oxygen.
Carbonic oxide .	6	8	or per cent.	42.86	57.14
Carbonic acid . .	6	16, or 8 × 2	„	27.27	72.73

(135.) We have seen that in instances of the compounds of oxygen and nitrogen there are as many as five distinct combinations of the same elements; we will examine these a little more minutely. These are—

	Containing pts. Nitrogen.	Oxygen.
Protoxide of nitrogen .	14	8
Deutoxide	14	16, or 8 × 2
Hyponitrous acid . . .	14	24, or 8 × 3
Nitrous acid	14	32, or 8 × 4
Nitric acid	14	40, or 8 × 5

(The cross stands for the words "multiplied by.")

Hyponitrous acid was discovered after the other compounds, and its discovery was entirely due to its being looked for, to make up the series.

Sometimes only part of the series is discovered. us, take the compounds of chlorine with gen :—

	Containing pts. Chlorine.	Oxygen.
Hypochlorous acid . .	36	8
Wanting.		
Wanting.		
Chlorous acid	36	32, or 8 × 4
Chloric acid.	36	40, or 8 × 5
Wanting.		
Hyperchloric acid . . .	36	56, or 8 × 7

e future progress of the science may possibly up the gaps, and so complete the series.

The same law holds good in secondary comations; for example, sulphate of potash conns—

Sulphuric acid, 40; potash, 48.

sulphate—

Sulphuric acid, 80; potash, 48.

Again, in the subsalts of lead—

	Oxide of Lead.	Nitric Acid.
Nitrate of lead . . .	112	54
Dinitrate	224 = 112 × 2	54

In all these cases we observe that combination es place in multiple proportions.

(136.) We are not to conclude that because the ne compound always has the same composition, t therefore the same composition always proces the same substance. We have seen that *a* osphoric acid, *b* phosphoric acid, and *c* phosphoric d have different salts, though their composition the same. The like is true of cyanic, cyanuric d fulminic acids and cyamelide. The instances *isomerism*, as this property is called, are very merous in organic chemistry. The word isomeis made up of two Greek words, and means ual parts.

(137.) The third law next demands our attention, and is most important. The question naturally arises, How much of any chemical substance is required to produce a given effect? Suppose we had 54 grains of carbonate of soda, which consists of—

Carbonic acid . . .	22 grains,
Soda	32 „

we might neutralize this with different acids; we should find by experiment that it would take, of

Dry	Grs.		Grs.	
Sulphuric acid .	40	equal to	49	of strongest oil of vitriol.
Nitric acid . .	54	„	63	nitric acid. Sp. gr. 1.5.
Chloric acid . .	76	„	85	strongest liquid chloric acid.
Iodic acid . .	166	„	175	ditto iodic.
Tartaric acid .	132	„	150	crystallized acid.

The carbonate of soda would be dissolved with effervescence in each of these acids, from the escape of the 22 grains of carbonic acid; we might too have chosen any other base, such as lime; and though we might require a different quantity of the acids, we should still have to use them in the same proportions. Thus, had we taken 14 grains of quicklime, or 25 grains of chalk, we should have found it only required 20 grains of dry sulphuric acid, and 27 grains of nitric acid, and so on. If we take 40 to be the equivalent of sulphuric acid, as we shall shortly see reason to do, then the other numbers will be the equivalents of the acids against which they are placed. The experiment is very easily made; if a little infusion of violets be put into the carbonate of soda, it will turn green; when the solution is neutral the blue will be restored, and if acid be in excess, it will turn red.

(138.) It is easy to extend the same reasoning to the simple bodies. A different quantity of each substance is required to combine with another; and if one substance displace another from its combinations, it is this quantity that will do it. For example, if we decompose 17 grains of sulphuretted hydrogen, with chlorine, we must use 36 grains of this latter substance; if with iodine, 126 grains, and so on: and it takes more in proportion as the equivalent is high. This is a circumstance which the chemical manufacturer must always carefully attend to; if several substances will answer his purpose equally well in all other respects, he will always use that which will have the lowest equivalent, because it will take less of it. Thus, for example, lime is used to purify gas; but it will not absorb the sulphuretted hydrogen, without a good deal of agitation: acetate of lead instantly takes every particle of sulphuretted hydrogen that is passed through it, till the lead is all converted into sulphuret. As the purification of coal gas is of great commercial importance, a patent was taken out for purifying with acetate of lead. A practical manufacturer was asked what he thought of the scheme; he answered, "It will never do, it takes such a quantity." The equivalent of lime is 37; of the crystals of acetate of lead, the form in which it is sold, 190: it would, then, take more acetate of lead to take out the sulphuretted hydrogen, than it does lime, in the proportion of 190 to 37, or 5 to 1. As acetate of lead is very much dearer than lime, at least 10 times, the expense of purification would be as 50 to 1.

(139.) Since it is the *proportion*, merely, which it takes of different substances to displace one another, and not the *absolute* quantity, which determines the equivalent, it is manifest that it is quite a matter of choice what substance we take to start with, and by what number we represent it; we might, as is very common on the Continent, take oxygen at 100. In this case, the equivalent of hydrogen will be 12.5; carbon, 75; nitrogen, 175.75; or 100 grains of oxygen unite with 12½ hydrogen, 75 carbon, &c. Hydrogen is, however, preferable; it takes less hydrogen than any other substance to displace any of the elements; and, if we assume hydrogen 1, then oxygen will be 8, carbon 6, &c., or these will be the number of grains of these substances which will respectively unite with one grain of hydrogen. Another advantage will be, that we may then suppose all the equivalents to be whole numbers, the errors thus produced lying within those which are incidental to the best experiments. Many persons, indeed, have supposed that all the equivalents on the hydrogen scale, that is with hydrogen 1, are whole numbers; if so, those that we have used in this work will be exact. Unless, however, some reason can be shown why they should be so, the probabilities are against this view. The reason we have not in this treatise used any but whole numbers as equivalents, is to make it more useful to those who do not understand decimals.

(140.) The next thing is to determine the equivalents. This we can do very readily by experiment. We have, for example, found that, to form water, requires two measures of hydrogen to one of oxygen; but, on looking to the weights of 100 cubic inches, we find oxygen is just sixteen times heavier than hydrogen; hence water consists, by weight, of 8 parts oxygen to 1 of hydrogen; therefore, assuming water to be a protoxide, 8 is the equivalent of oxygen.

The same thing is equally easy, if the composition is given per cent.; thus, if we take sulphuretted hydrogen, we might, by decomposing it with chlorine, as mentioned in section (87), extract from 100 grains of the gas—

94.1 grains of sulphur;
Leaving 5.9 grains of hydrogen.

Now, if we assume that sulphuretted hydrogen is composed of single equivalents of its elements, we have only to do the following rule of three sum:—

Hydrogen. Grains Sulph. Standard Equiv.
5.9 : 94.1 :: 1 : 16 the answer.

Therefore 16 is the equivalent of sulphur.

Take another instance, sulphurous acid: 100 grains of sulphurous acid contain exactly equal quantities of sulphur and oxygen That is—

Sulphur	50
Oxygen	50

The sum is—

Sulph. Oxygen. Equiv.
50 : 50 :: 8 : 8.

This equivalent is half what we obtained above; the reason is evident, sulphurous acid contains two equivalents of oxygen; the sum, therefore, should have stood thus: 50 : 50 :: 2 × 8 : 16, which agrees with the equivalent deduced above.

(141.) The question then arises, How shall we determine what compounds are composed of single equivalents? Analogy and convenience alone determine this; for example, we might have supposed sulphurous acid to contain one equivalent of oxygen, but then we must have supposed sulphuretted hydrogen to contain two equivalents of sulphur; a view which would be inconsistent with analogy, and also at variance with the saturating power of sulphuric acid.

Since by Law IV. the equivalent of a compound is obtained by adding the equivalents of its elements, we may very often determine the equivalent of an element, from that of a compound; for example, carbonate of lime, or chalk, consists of 45 per cent. of carbonic acid, and 55 of lime. If lime be, as analogy leads us to suppose, a protoxide of calcium, what is the equivalent of calcium? First, to find the equivalent of lime:

Carb. Acid.		Lime		Equiv. of Carb. Acid.		
45	:	55	::	22	:	28 equiv. of lime.

Therefore 28 is the equivalent of lime; and, if this be a protoxide, it must contain 8 grains of oxygen, and 20 of calcium; therefore 20 is the equivalent of calcium. It would be very difficult indeed to determine the equivalent of calcium directly. The same kind of question may be proposed in another form: the saturating power, or equivalent, of dry sulphuric acid, is 40; if it consists solely of sulphur and oxygen, how many equivalents of the latter? the equivalent of sulphur being known to be 16, and oxygen 8.

Since 16 parts are sulphur, the remaining 24 are oxygen; but $24 = 3 \times 8$; therefore sulphuric acid contains 3 equivalents of oxygen.

How much real acid is there in 100 parts of the strongest concentrated oil of vitriol?

We have seen that oil of vitriol, as concentrated as possible, consists of 40 parts sulphuric acid, and 9 of water, being a protohydrate of sulphuric acid; therefore—

Equiv. of Sulph. Acid. Real Acid.
49 : 40 :: 100 : 81.63;

so that nearly 82 parts in 100 are real acid. By methods such as these the numbers in Table I. Col. IV. have been calculated.

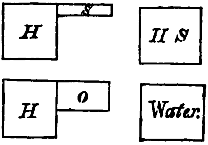
COMBINATION BY VOLUME.

(142.) All our former calculations have been made with regard to *weights;* we find, however, that the *bulks* in which gases combine bear a simple relation to each other. Thus, the reader cannot have failed to notice, that whenever we have had occasion to measure out the quantity of hydrogen necessary to combine with oxygen, we have always had twice as much of the former as of the latter; hence oxygen and hydrogen combine in the proportion of two vols. of hydrogen to one of oxygen. Nitrous oxide we found combined in the same manner, two vols. nitrogen to one oxygen. Nitric oxide, again, of equal volumes. And the same thing may be observed running through all the combinations of gases, and even vapours. From all this it is evident that there must be a relation between the specific gravity and the equivalent of gases and vapours: this will appear from the accompanying table. We are not to be surprised that we did not discover this relation when the specific gravity was referred to air; but the moment we refer it to hydrogen, that is, multiply the numbers in Col. III. by 16, since air is nearly 16 times heavier than hydrogen, we obtain the numbers in Col. IV., and the relation is manifest. It will be observed, however, that sulphur is 6 times, and oxygen, phosphorus, and arsenic, twice as heavy as the

TABLE IV.

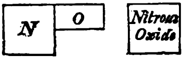
I.	II.	III.	IV.
Name of Substance.	Equivalent.	Specific Gravity Air = 1.00.	Specific Gravity, Hydrogen = 1.00.
Sulphur .... $\frac{1}{6}$ ▭	16	6.900	96 = 16 × 6
Oxygen .... $\frac{1}{2}$ ▭	8	1.1093	16 = 8 × 2
Phosphorus .... $\frac{1}{2}$ ▭	32	4.420	62.8 = 32 × 2
Arsenic .... $\frac{1}{2}$ ▭	75	10.600	150.4 = 75 × 2
Hydrogen .... ☐	1	0.0693	1 = 1 × 1
Iodine .... ☐	126	8.71	126 = 126 × 1
Bromine .... ☐	78	5.54	78 = 78 × 1
Chlorine .... ☐	36	2.4543	35 = 36 × 1
Nitrogen .... ☐	14	0.9706	14 = 14 × 1
Mercury .... ☐	101	6.9760	101.4 = 101 × 1
COMPOUND GASES.			
Steam .... ☐	9	0.6239	9 = 9 × 1
Hydrochloric Acid .... 2 ☐☐	37	0.9359	18.5 = 37 × $\frac{1}{2}$
Ammonia .... 2 ☐☐	17	0.5893	8.5 = 17 × $\frac{1}{2}$
Hydrochlorate of Ammonia 4 ⊞	54	0.8900	13.5 = 54 × $\frac{1}{4}$

equivalent would lead us to expect; but then we find that oxygen combines in half volumes, and sulphur in one-sixth volumes; that is, sulphuretted hydrogen is, by bulk, $\frac{1}{6}$th sulphur vapour to 1 vol. of hydrogen; and water consists of $\frac{1}{2}$ vol. of oxygen to 1 vol. of hydrogen, as represented in the figure. The square representing 1 cubic inch, foot, &c. of hydrogen; and the half-square, $\frac{1}{2}$; and the oblong marked S, $\frac{1}{6}$th of this quantity.



Sometimes condensation ensues on combination; sometimes, though more rarely, expansion; sometimes the bulk remains the same. For example, nitrous oxide consists of, by volume—

$\frac{1}{2}$ oxygen
1 nitrogen

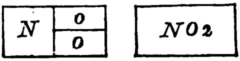


one vol. nitrous oxide.

Hence condensation has ensued.

Again, nitric oxide consists of—

1 nitrogen
2 oxygen

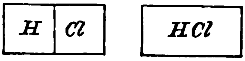


2 vols. of nitrous oxide;

or, the elements are united without condensation.

Again, hydrochloric acid consists of—

1 hydrogen
1 chlorine



2 vols. hydrochloric acid;

or, union takes place without condensation.

It may so happen that the compound of the gases is a liquid, or even a solid, at common temperatures; thus, water is a liquid, but if we raise it to steam, we shall find that it is composed of a vol. of hydrogen and half a vol. of oxygen condensed into one vol. This might be shown by measuring and exploding the gases at the temperature of boiling water.

(143.) Carbon has never been raised into vapour, but still we may form a very good guess of the specific gravity of carbon vapour, for analogy gives us reason to suppose that carbon combines in half volumes, like oxygen; its specific gravity, therefore, is to oxygen as 6 : 8, that is 0.832; and this, or some multiple of it, will no doubt be found to be the specific gravity of carbon vapour, should it ever be vaporized.

There are also some curious relations to be observed in the combining volumes of solids, but they are of too speculative a nature to be inserted in an elementary treatise like the present. The student who is curious on this point is referred to the translation of Gmelin's handbook, in the works of the Cavendish Society.

CHEMICAL SYMBOLS.

(144.) It has been found very convenient to have some abbreviation which shall save us the trouble of writing the whole name of a chemical substance; and, if it were for this reason alone, symbols would be desirable. They have a further advantage, however, that they can be so contrived as to present to the eye the complete constitution of compound substances. The symbol, then, is the first letter of the Latin name of the substance, in capitals; and, where two or more begin with the same letter, another small letter is added, for distinction (see Table I.); if more than one equivalent of the substance is taken, a number is appended denoting how many. When no number is appended the number 1 is supposed; for example, O^1 or O is one equivalent of oxygen, O^2 two equivalents, and so on. The number may be written either before or after, above or below, thus O_2, 2 O, O^2 all mean the same thing. The symbol of a compound is formed by writing down the symbols of its components, either with the sign (+) (read plus) between them, or with a comma, or merely writing them together; for example, water is $H + O$ or H, O or $H O$. Sometimes all the different symbols are used in the same formula; in which case we use the last, to signify the closest and most intimate union. A few examples will make this plain:—

Hydrochloric acid is . . .	$H + Cl$	or H, Cl	or $H Cl$.
Sulphuric acid is	$S + 3 O$	or S, O^3	or $S O^3$.
Soda is	$Na + O$	or Na, O	or $Na O$.
Sulphate of soda is. . . .	$Na O + S O^3$	or $Na O, S O^3$.	
Crystallized carbonate of soda	$Na O, C O^2 + 10 H O$.		

the acid always being placed last.

Sometimes one or more of the elements are written together in a bracket, and a number before them; if so, the whole quantity in the bracket is to be multiplied by that number. For example, $2 (Na O + S O^3)$ means two equivalents of sulphate of soda; sometimes the bracket is omitted, and then the number multiplies every thing to the next sign, as $2 Na O \, S O^3$ means two equivalents of sulphate of soda, while $2 Na O, S O^3$ would mean two equivalents of soda, and one of sulphuric acid; these symbols are very conveniently used to express decompositions and chemical changes. For example: in the case of nitric acid from nitrate of soda, we have—

$$(NaO + NO^5) + (SO^3 + HO) = (NaO + SO^3) + (NO^5 + HO)$$

those quantities in the brackets on the left being the materials, and those on the right the results. Written in words, this would be, nitrate of soda and hydrate of sulphuric acid, become sulphate of soda and hydrate of nitric acid.

Again, in the preparation of chlorine with peroxide of manganese and hydrochloric acid, we have—

$$2\,HCl + Mn\,O^2 = Mn\,Cl + 2HO + Cl.$$

or in words, two equivalents of hydrochloric acid with one of peroxide of manganese, give one equivalent of chloride of manganese, two equivalents of water, and one equivalent of chlorine, which is given off. Of course, when the compounds are complicated, the symbol is so; for example, crystallized alum is a double sulphate alumina, and potash, with a considerable number of equivalents of water; its symbol is

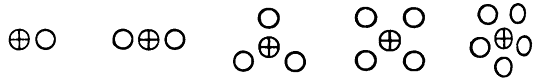
$$Al^2\,O^3, 3SO^3 + KO, SO^3 + 24\,HO.$$

This is, perhaps, an advantage, rather than otherwise. Some authors use abbreviations. Thus, two equivalents are denoted by drawing a line through, or under the symbol. Oxygen is represented by dots, and sulphur by commas. For example; sesquioxide of iron Fe^2O^3 or $\underline{\dddot{F}e}$; bisulphuret of carbon CS^2 by $\overset{,,}{C}$; alum $\underline{\dddot{Al}}\,3\dddot{S} + K\dddot{S} + 24\,\dot{H}$. These are of little use in writing, and very inconvenient in printing.

ATOMIC THEORY.

(145.) A great deal of controversy took place in ancient days as to whether matter is infinitely divisible, or whether it consists of ultimate particles which are not divisible by mechanical means. We have no direct methods of determining this, as the particles of matter must be far too small to be rendered visible to the eye, even by the most powerful microscopes. The smallest fragment of flint, for example, looks nothing more when under the microscope, than a larger fragment would do without it. Nevertheless, chemistry gives us indirect means for answering the question, and answering it in favour of the hypothesis of ultimate indivisible atoms.

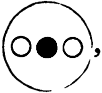
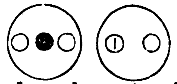
(146.) Suppose, then, a substance to consist of small hard particles of matter, which are incapable of being divided; (these particles are called atoms, from a Greek word, signifying the impossibility of division;) if we imagine them to be of weights proportional to their equivalents, and to take up equal, or at least, proportional spaces, then we shall have an explanation of the laws both of combination by volume and weight. Suppose, for example, the ○ ● open circle to represent a particle of oxygen, and the black one of carbon; then the two together will represent a *compound atom* of carbonic oxide, and a substance made up of such atoms must necessarily consist of oxygen and carbon in the proportion of the weights of their respective atoms; or, in this case, six to eight, since that is the proportion of the weight of the atom of carbon to that of the oxygen; if we add another atom of oxygen, then we may suppose the arrangement of the atoms to be represented by ○●○ which will represent carbonic acid, and this must consist of 16 parts oxygen to 6 carbon. If we represent nitrogen by ⊕ we have—

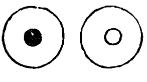


representing what may be supposed to be the arrangement of the atoms of nitrogen and oxygen; the four last manifestly containing twice, three times, four times, five times the oxygen of the protoxide. Again, we see that we may have 2 atoms of one compound with 3 of another, 5 with 7, and so on; but such are rare.

(147.) The student may possibly find that it will assist him in this theory, if we suppose the atoms of oxygen to be represented by shot, and those of carbon by peas; then, if eight peas weigh as much as six shots, the compound atom of carbonic oxide would be represented by a pea and a shot together, and a quantity of carbonic oxide by a great number of such compound atoms: if the student were to pick out the peas and the shot, he would, of course, find that the weight of all the peas was to the weight of all the shot as six to eight. Carbonic acid, again, would be represented by adding another shot to each pair of a pea and a shot, which made up the carbonic oxide; and the analysis of carbonic acid would be in like manner represented by separating the shot from the peas, when the weight of the shot must be to that of the peas as 16 to 6. We might also have a compound represented by 2 peas and 3 shot, which would resemble in constitution oxalic acid, or 5 peas to 7 shot; but no such compound of carbon and oxygen has been discovered which would be represented by such an arrangement.

(148.) Hence not only must all compounds be definite, but if there be more than one between the same elements, these must be in multiple proportion. Again, the law which gives the equivalent of the compounds as the sum of the equivalents of the elements admits of equally simple explanation; since, for example, the compound atom ○●○ must have the weight of its elements. We might illustrate this by saying, that a pea and two shot weigh as much together as separately.

(149.) The compound atoms (which we have represented by putting the compounding atoms in a circle), as long as they remain together, are supposed to combine just in the same way as the simple ones; thus, carbonic acid is , and if we represent calcium by ⦶, and lime therefore by ○⦶, carbonate of lime is  or the combination is the same as though carbonic acid and lime were elements. If the atoms be the same size, or, rather, if they occupy the same space, (for they are not supposed to be in contact, but imagined to be surrounded by a sphere of heat like the atmosphere which surrounds our globe,) then, if the spheres be of the same size, the substances will combine in equal volumes;



if one should be half that of the other, then in the proportion of two volumes to one, and so on; this would also account for heat being given out when two bodies contract in uniting, though it must be confessed that very often heat is given out even when they expand; as, for example, when chloride of nitrogen explodes, expanding into gaseous chlorine and nitrogen. In accordance with this theory, the equivalent weight is sometimes called the atomic weight.

NOMENCLATURE.

(150.) It is manifest that when we have to deal with such a variety of substances as chemistry presents to our notice, we must have some system of classifying and naming them, as it would be quite impossible to remember a number of names which were merely arbitrary. A system, therefore, has been invented, which merely requires us to remember the names of the elements, and forms the names of all compounds out of them.

(151.) All combinations of chlorine, iodine, bromine, fluorine and oxygen, with the metals and other elements, are respectively called chlor*ides*, iod*ides*, brom*ides*, fluor*ides*, ox*ides*, of these elements. The combinations of the other elements with the metals, or each other, are distinguished by the termination *uret*, as sulph*uret*, phosph*uret*;* and, in some cases, the same is extended to compounds of metals, as arseniuret, telluret, antimonuret. The different proportions of oxygen are denoted by prefixing *proto*, *deuto*, or *bin*, *trito*, or *ter*, as protoxide, deutoxide; the protoxide contains one equivalent of oxygen, the deutoxide two, and so on; the peroxide denotes the highest degree of oxidizement not possessed of acid properties. When the proportion of oxygen is to that of metal as three to two, the combination is called a sesquioxide, as sesquioxide of iron (*sesqui* is the Latin for one and a half); an oxide, containing less oxygen than the protoxide, is called a sub-oxide; if the oxide consist of two proportions of metal to one oxygen, a dioxide; if three metal to one oxygen, a trisoxide, and so on. The same holds good with other elements, as persulphurets, dichlorides, &c.

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* Sulph*ide*, phosph*ide*, &c. are also sometimes used.

(152.) Though, strictly speaking, a compound of oxygen exhibiting acid properties is also an oxide, it is usual to give it another name; if there be only one acid, it is distinguished by the termination *ic*, as carbon*ic* acid. If two acids contain different proportions of oxygen, that with least oxygen ends in *ous*, that with most in *ic*, as arseni*ous*, arsen*ic* acid. If there be more than two acid compounds with the same elements, they are called, like the sulphur acids, *hypo*sulphur*ous*, sulphur*ous*; *hypo*sulphur*ic*, sulphur*ic* acid. Occasionally, the acid containing the most of all, is denoted by the prefix *per*, *oxy*, or *hyper*, as *per*chloric, *hyper*manganic acids.

(153.) Salts are called after the acids; those salts which arise from the combination of an acid whose name ends in *ous*, have their names terminating in the syllable *ite*, as sulphurous acid forms sulphites; those from acids ending in *ic*, end in *ate*, as sulphuric acid, sulphates. Sometimes two, three, &c., equivalents of acid unite with one of base; then the syllables *bi*, *tri*, &c., are prefixed, as *bi*-sulphate. If, on the other hand, two equivalents of base unite with one of acid, the syllable *di* is prefixed, as *di*nitrate of lead. Sometimes, though rarely, both the protoxide and the peroxide of a metal are bases; in which case, we have *proto*salts and *per*salts, as *proto*sulphate of iron, *per*sulphate of iron. Latterly another nomenclature has been adopted, which deserves to be used from its great clearness; the protoxide of iron is called ferr*ous* oxide; the sesquioxide, ferr*ic* oxide; and then the protosulphate is called sulphate of ferrous oxide, or ferrous sulphate; the persulphate, sulphate of ferric oxide, or ferric sulphate. Properly speaking, we ought to say sulphate of oxide of copper, sulphate of oxide of zinc, &c.; the word oxide is generally left out, and no mistake can arise, since acids do not unite directly with metals.

(154.) The acids which are formed by the union of hydrogen with an element, are called hydracids, and have the syllable hydro prefixed, as hydrochloric acid.

(155.) The compounds of water with acids and bases are called hydrates.

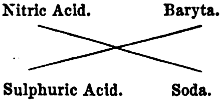
AFFINITY.

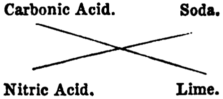
(156.) The power which causes the different elements to unite and form compounds, with properties different from the elements of which they are composed, is called chemical affinity, or attraction. The property of forming new compounds distinguishes this force from that of mere adhesion, where the bodies are simply mixed, and still retain their original properties, though it is not possible to draw the precise line which separates chemical combination from mechanical mixture, as one graduates by almost insensible degrees into the other. The affinity, too, which exists between the elements is very different: as a general rule, it is most powerful between those bodies whose properties are most opposed. For example, hydrogen and the metals show a strong disposition to unite with oxygen, chlorine, &c., but very little tendency to combine with one another. Sulphur, phosphorus, &c. stand midway, and combine readily with either. Yet, again, the affinity between oxygen and the metals is so different, that while potassium will take oxygen from every combination of it with the other elements, oxide of gold is decomposed by the agency of light alone.

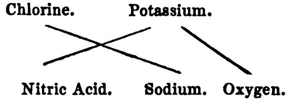
(157.) It is by means of this force of chemical affinity that we are enabled to effect the decomposition of compound bodies. In by far the greater number of instances we isolate one element of a compound by adding to it a substance which has a superior affinity for the other element or elements. This process goes by the name of elective affinity. The production of carbonic acid by dilute nitric acid is an instance of this. We add to the carbonate of lime an acid which has a greater affinity for the lime than carbonic acid; nitrate of lime results, and carbonic acid escapes. In the same way we might, by the help of heat, displace the nitric acid by sulphuric acid; and hence we say that sulphuric acid has a greater affinity for lime than nitric, nitric than carbonic acid.

(158.) It is nevertheless very difficult to determine the precise order of the precedence of affinity, so greatly is it influenced by external circumstances; and where affinities are nearly balanced, sometimes a very trifling circumstance will serve to turn the scale; for example, a difference of solubility or of volatility. Formerly great pains were taken to construct tables containing the precedence of affinities; these are, however, of little use, as they do not give us the absolute order in which they stand to each other, but only that which exists under the circumstances in which the experiments were made; and the possible variations are so numerous, that there is no means of discovering what is due to them and what to the real amount of affinity actually existing between the substances. It is, however, well for us that it is so: were it otherwise, it would be almost if not altogether impossible to separate two substances whose affinities were very great. We can, as we have already seen, only do so by displacing the one we desire to isolate, by the addition of a third having a greater affinity for the other element; and it is evident that it would in many cases be difficult to find such a substance: as it is, by the agency of heat, solution, &c. we can take advantage of some circumstance which shall make the less affinity preponderate. For example, the affinity of potassium for oxygen is so great, that it will take it from all other substances containing that element; nevertheless carbonate of potash is decomposed by heating it with charcoal, and potassium being *volatile* distils over; the decomposition is no doubt due to this circumstance; and though the affinity of carbon for oxygen is probably not so great as that of potassium, its tendency to form vapour at a white heat is the external circumstance which determines the decomposition. Again, in the instance given above, no acid is sufficiently powerful to displace sulphuric acid in the *cold.* Phosphoric and silicic acid will do so at a *white heat,* the volatility of *sulphuric* acid at a high temperature favouring the decomposition. Again, if steam be passed over iron heated to redness, it is decomposed, and hydrogen is given off, and oxide of iron formed; while if hydrogen gas be passed over red-hot oxide of iron, water is formed, and iron reduced; in both cases, however, a considerable excess is required of the hydrogen in one case, and steam in the other; and we may suppose that the affinity is so nearly balanced as to be determined by the circumstance, that in one case the hydrogen tends to diffuse itself in an atmosphere of steam, and in the other, that the steam tends to diffuse itself in the atmosphere of hydrogen. Another instance of the same thing is, that carbonate of ammonia precipitates carbonate of lime from solution of chloride of calcium, and hydrochlorate of ammonia remains dissolved; while, on the other hand, if crystallized hydrochlorate of ammonia be mixed with carbonate of lime and exposed to heat, carbonate of ammonia volatilizes; the reason of this is, that carbonate of lime is insoluble, while carbonate of ammonia is more volatile than hydrochlorate. As a general rule, the more insoluble salt precipitates from a solution, and the more volatile element rises from a distillation, when a decomposition takes place in either case.

(159.) DOUBLE DECOMPOSITION, of which the last example is an instance, is of such importance that it is necessary to say something concerning it. When two solutions of neutral salts are mixed, there very often is an entire transfer between the acids and the bases; for example, if we mix sulphate of soda and nitrate of baryta, a complete interchange of acids and bases will take place; the sulphuric acid will leave the soda and go to the baryta, and the nitric acid will leave the baryta and go to the soda. Now, sulphate of baryta is entirely insoluble, and therefore the moment the mixture is made, the sulphate of baryta makes its appearance as a white cloud, which falls to the bottom of the vessel as a white precipitate. In the same way, if we add carbonate of soda to nitrate of lime, carbonate of lime precipitates, and nitrate of soda remains in solution. Again, difference of solubility has often the same effect as absolute insolubility; for example, if we mix nitrate of soda and solution of chloride of potassium, nitrate of potassa, the more insoluble salt, crystallizes out, leaving chloride of sodium in solution.







The above shows these decompositions, the cross lines pointing to the elements which combine. Sometimes, however, absolute insolubility is insufficient to determine a reaction against very powerful affinities. For example, sulphate of baryta is quite insoluble, yet it may be partially decomposed by boiling it with carbonate of potash, though in a dilute and cold solution baryta will decompose sulphate of potash.

(160.) This property which the insoluble salts have of precipitating out of solutions in which they are formed, may be simply explained thus, by reference to an example. Suppose we boil muriatic acid with sulphate of copper (which is blue), we are sure that chloride of copper (which is green) is formed, as the colour of the solution changes from blue to greenish, though in what proportion the copper divides itself between the sulphuric and muriatic acid it is impossible to tell. Suppose, however, we mix nitrate of baryta and sulphate of soda, we may suppose that we have all four salts in solution, the acids dividing themselves between the bases in proportions depending on their respective affinities; namely, nitrate of soda, nitrate of baryta, sulphate of soda, and sulphate of baryta; this last being insoluble precipitates, and is thus removed from the action; a fresh proportion of sulphate of baryta is then formed, and is again precipitated, and so on till all the sulphuric acid or all the baryta are removed from the liquid. Hence we see that even if we could suppose the affinity between sulphuric acid and baryta to be so small that a very minute portion of sulphate of baryta would be formed if it were soluble, yet, as it is insoluble, it will nevertheless remove all the sulphuric acid, for the moment the least quantity of sulphate of baryta is formed it is removed by precipitation, and the acids again divide themselves among the bases, as if no sulphate of baryta had been formed, and so on until the whole of the sulphuric acid is transferred to the baryta.

This property is taken advantage of in chemical analysis; we will also illustrate this by a simple example. Vinegar is sometimes fraudulently adulterated with sulphuric acid; this is easily detected by adding to it a solution of nitrate of baryta as long as precipitate falls; this may be collected, washed, and dried, and the amount of sulphuric acid estimated from the weight of the sulphate of baryta, 100 grains of sulphate of baryta corresponding to 34.2 of sulphuric acid.

(161.) Heat, it may be readily imagined, is a most powerful agent in determining the results of chemical affinity; and a great many bodies combine under the influence of a high temperature, which have no action on each other in the cold; sometimes, however, heat will produce decomposition; and again, it happens that raising the temperature will facilitate composition up to a certain point, while further increase will cause decomposition. This is the case with mercury, which combines with oxygen at a heat a little below redness, and is decomposed a little above. Precisely the same thing takes place with palladium.

(162.) Disposing Affinity.—The presence of a third body will sometimes determine the formation or decomposition of a compound: for example, when nitrogen is passed over red hot charcoal in the presence of an alkali, cyanogen is formed, which unites with the metal of the alkali. In the same way peroxide of manganese, when heated in the air with potash or soda, becomes manganic acid, which combines with the base. In these cases it appears that the affinity of the resulting compounds for the third substance assists their formation. Sometimes, however, a third substance influences a chemical decomposition without changing itself, as peroxide of manganese assists the decomposition of chlorate of potash, and oily substances explode chloride of nitrogen without undergoing any change themselves. This last property is called by the name of *catalysis;* and the bodies which behave thus are said to exercise a *catalytic* action.

CHAPTER IV.

METALLIC ELEMENTS.

(163.) WITH the more important of these elements the student is already familiar. Their most striking feature is their metallic lustre; which is at once recognised, though so difficult to describe.

(164.) Many of them are MALLEABLE, or are capable of being beaten into thin leaves. Gold is so malleable that it may be beaten into leaves so thin that a book of 200,000 of them would not be an inch thick. The following Table contains (Col. I.) the malleable metals, the most so being placed first.

(165.) Connected with this property is that of DUCTILITY, or the property that admits of their being drawn into wire. Column II. of this table shows the order of ductility of the metals.

(166.) The reverse of this is BRITTLENESS. The order in which they stand in this respect is given in Col. I., the most brittle being placed last. A bar of antimony will break like a piece of glass, and may be readily pounded in a mortar. The brittle metals are generally crystalline. Zinc stands midway between the brittle and ductile metals.

(167.) The STRENGTH OF TENACITY of different metallic wires is also very different. Column III. contains a table of the tenacity of the metals, the number being the number of pounds they will support.

I.	II.	III.	IV.	V.
Malleability.	**Ductility.**	**Tenacity.**	**Hardness.**	**Melting Points.**
Gold. Silver. Copper. Tin. Cadmium. Platinum. Lead. Zinc. Iron. Nickel. Palladium. Potassium. Sodium. Mercury (Frozen). Zinc(intermediate). **Brittleness.** Rhodium. Uranium. Tungsten. Titanium. Tellurium. Molybdenum. Manganese. Columbium. Cobalt. Chromium. Cerium. Bismuth.	Gold. Silver. Platinum. Iron. Copper. Zinc. Tin. Lead. Nickel. Palladium. Cadmium.	Iron .... 549 Copper ...... 302 Platinum ... 274 Silver .... 187 Gold .... 150½ Zinc .... 109½ Tin .... 34½ Lead .... 27½ The numbers are the pounds supported by wires 0.787 line in diameter.	Titanium, Manganese, } Harder than Steel. Platinum, Palladium, Copper, Gold, Silver, Tellurium, Bismuth, Cadmium, } Scratched by Calc. Spar. Iron, Chromium, Rhodium, } Scratch Glass. Nickel, Cobalt, Iron, Antimony, Zinc, } Scratched by Glass. Lead. Potassium, Sodium, } Scratch by the nail. Mercury, liquid.	Mercury........................ −39° Potassium..................... 136° Sodium .... 190° Tin.................................. 442° Cadmium .... 450° Bismuth .... 497° Lead .... 612° Tellurium, less fusible than Lead. Arsenic, undetermined. Zinc .... 773° Antimony, little below redness. Silver .... 1,873° Copper .... 1,996° Gold .... 2,016° Cobalt. Iron, cast .... 2,786° Iron, malleable, the highest heat of a Smith's forge. Manganese, ditto, ditto. Nickel, same as Cobalt. Palladium, Molybdenum, Uranium, Tungsten, Chromium, Titanium, Cerium, Osmium, Iridium, Rhodium, Platinum, } Infusible, except by the oxyhydrogen blowpipe.

(168.) The specific gravity of the metals is given in Table I. Potassium is the lightest, and platinum the heaviest. The order of the HARDNESS of the different metals is given in Column IV.

(169.) FUSIBILITY.—All the metals melt. Col. V. contains the order of their fusibility. Mercury melts at 40° below 0°; platinum, at 3,280° above.

Some of the metals are VOLATILE. Mercury boils at 600°; potassium, sodium, zinc and cadmium, at bright redness; and arsenic and tellurium are also volatile, though the exact temperature has hardly been determined.

OXIDES.

(170.) All the metals unite with oxygen; and a great number of these combinations are basic, that is, possess the property of combining with and neutralizing acids. It is usually the protoxide which is basic; the deutoxide is more commonly not so. A further addition of oxygen sometimes converts the oxide into an acid. Manganese is an instance of this; the protoxide is basic, MnO; the peroxide, MnO^2, neutral; MnO^3, is acid. Most of the oxides unite with definite proportions of water to form hydrates.

By far the greater number of the metallic oxides may be *reduced*, or obtained in the metallic state, by heating with charcoal or some other form of carbon. The process used in the arts to obtain he metals is almost always to convert the ore nto an oxide, by proper methods, and then reduce with carbon.

CHLORIDES.

(171.) All the metals may be made to unite with chlorine; in some the affinity for this element is even greater than that for oxygen. Thus, if chlorine be passed over lime, magnesia, baryta, strontia, potassa, or soda, at a red heat, oxygen is evolved, and a chloride of the metal formed; and it is only by a circuitous process that the metals can be again procured in the state of oxides.

The action of hydrochloric acid has been already noticed.

IODIDES AND BROMIDES.

(172.) Resemble the chlorides; they are, except in a very few cases, of little practical importance.

SULPHURETS.

(173.) All the metals unite with sulphur; and some of these sulphurets are important ores. The sulphates may be converted into sulphurets by heating with charcoal; this method is extensively resorted to in the preparation of sulphuret of sodium. They are mostly insoluble, and many of them have a metallic lustre. Sulphuretted hydrogen acts on the oxides in a manner precisely analogous to hydrochloric acid.

The SELENIURETS resemble the sulphurets.

(174.) The PHOSPHURETS have not been much examined; they may be prepared by heating the phosphates with charcoal, or passing hydrogen over them at a red heat.

(175.) The CARBURETS are of no practical importance, with the exception of carburet of iron.

(176.) Nitrogen shows little disposition to unite with the metals. NITRURET of copper, Cu^6N, has been formed.

(177.) HYDURETS.—Hydrogen unites with arsenic, antimony, and tellurium.

(178.) The metals show but little tendency to unite among themselves. They may usually be fused together, and the mixtures thus made are called alloys; some of these are of extensive commercial importance, but few of them are definite chemical compounds.

SALTS.

(179.) This is the name given to those secondary compounds which result from the union of an acid with a base. When there are as many equivalents of acid in the salt as of oxygen in the base, the salt is said to be neutral, although in some few instances it is not neutral to test paper. By far the greater number of the salifiable bases are protoxides, and contain therefore one equivalent of acid and one of base. The sesquioxide or peroxide of iron is an instance of a salifiable base containing more oxygen than the protoxide. It so happens that the salts of the protoxide of iron have a tendency to absorb oxygen, and pass into salts of the peroxide; in which case the acid in the protosalt is insufficient to neutralize the base when converted in a sesquioxide. Thus, if protosulphate of iron be exposed to air it absorbs oxygen, and a persulphate and a sub-persulphate are formed. The change is as follows:—

4 equivalents of the protosulphate $= 4\ (FeO + SO^3)$,
absorb two equivalents of oxygen $= 2\,O$,

and become

one equivalent of neutral persulphate $= Fe^2O^3 + 3SO^3$,
one equivalent of basic persulphate $= Fe^2O^3 + SO^3$.

BINARY THEORY OF SALTS.

(180.) It was till very lately the universal opinion that neutral salts are compounds in which the acid exists as acid with the base as base; that is, sulphate of soda is $NaO + SO^3$; nevertheless, we might suppose the elements arranged differently, as

$$Na + SO^4, \text{ or } NaO^4 + S, \text{ or } NaO^2 + SO^2,$$

there being nothing we have as yet seen which leads us to suppose the elements to be arranged in one order more than another; there is reason to believe, however, that $Na + SO^4$ may be a better representative of sulphate of soda than $NaO + SO^3$.

It had long been observed that the hydracids neutralized bases with exactly the same phenomena as when an oxyacid was used. Thus, for example, if we drop hydrochloric acid into carbonate of soda, the carbonic acid will escape with effervescence; the carbonate (which is not neutral to test paper, though a neutral salt,) will gradually lose its alkaline flavour; and when the solution is quite neutral it will taste salt, and on evaporating it common salt will crystallize out. For a long time, therefore, common salt in solution was called muriate of soda, and was supposed in solution to be represented by the formula, $NaO + HCl$; nevertheless, it is more consistent with experiment to suppose that it is represented by $NaCl + HO$. It was from this analogy to common salt in composition that salts got their name. Yet if we define a salt to be the compound formed by the union of an acid and a base, *salt* is not a salt, being a binary compound of chlorine and the metal sodium. Yet on the other hand, the chlorides, iodides, bromides, &c. are so like the salts of the oxygen acids that they cannot be conveniently separated. A theory has, therefore, been proposed which assimilates these two descriptions of bodies, and has moreover the merit that it is supported by experiments with the galvanic battery; it is known as the binary theory of salts.

(181.) The student will recollect that a vast number of the oxyacids only exist in the state of hydrates; some of them, as chloric acid, are not known to exist except combined with one equivalent of water; dry chloric acid has never been isolated. But what is still more curious, even when we can obtain the anhydrous acids, they have no action on litmus paper, and show very little affinity for bases, requiring a high temperature to render them effective; this is the case with the anhydrous sulphuric and phosphoric acids. Telluric acid, when hydrated, combines with bases; but if all the water be expelled, which it may be by heat short of redness, it shows no disposition to unite with them, and is remarkably indifferent to all re-agents; in this case, the acid property depends entirely on water.

(182.) It seems, then, very probable, that hydrogen may, after all, be the acidifying principle of the oxyacids; thus we may regard oil of vitriol not as $SO^3 + HO$, but as $SO^4 + H$; and, in this case, the action of aqueo-sulphuric acid would be exactly analogous to that of hydrochloric acid. For example; when hydrochloric acid acts upon zinc, chloride of zinc is formed, and hydrogen given off;—

$$HCl + Zn = ZnCl + H;$$

in the same way—

$$(SO^4 H) + Zn = SO^4 Zn + H.$$

The combination SO^4 may therefore be regarded as a radicle, and $SO^4 H$ as its hydracid. It is true that SO^4 has never been isolated, but then the difficulty which thus arises is no greater than the supposition of dry chloric acid, which has also never been isolated. It is more consistent with experiment to regard aqueo-chloric acid as $ClO^6 + H$, assuming the existence of the oxygen radicle ClO^6, than of ClO^5. This, again, will account for the fact, that the number of equivalents of acid in the neutral salt is the same as the number of equivalents of oxygen in the base, thus; the sesquioxide of iron is $Fe^2 O^3$, and persulphate of iron formed by dissolving $Fe^2 O^3$ in aqueo-sulphuric acid, is—

$$3 (H SO^4,) + Fe^2 O^2, = Fe^2, 3 SO^4 + 3 HO.$$

as it is obvious that to form water with the oxygen of the base an equal number of equivalents of hydrogen must be derived from the acid.

(183.) The oxysalts of ammonia form no exception, for they invariably contain one equivalent of water, which cannot be driven off without decomposing the salt. On the old view, then, sulphate of ammonia would be $SO^3 NH^3 + HO$; but on the new it will be $SO^4 NH^4$; where NH^4 is equivalent to a metal, and has been called ammonium. The student will no doubt be surprised to find, as it were, a compound metal; but he has already had experience of a compound radicle, which combines like a non-metallic element in cyanogen. Hence, aqueous solution of ammonia may be considered as solution of oxide of ammonium, *i.e.* $NH^3 + HO = NH^4 O$. It is true that dry ammoniacal gas unites with the anhydrous acids, forming crystalline substances, but these are remarkably different from the ordinary ammoniacal salts.

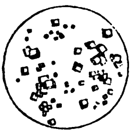
(184.) It thus appears that perhaps hydrogen, and not oxygen, may be the acidifying element. This renders the name oxygen peculiarly unfortunate; it means acid generator, and was thus named from what was, at best, too hasty a generalization, as oxygen, even on the old theory, cannot be considered as the only generator of acids, and not at all so on the new.

Since the above was written, dry nitric acid has been isolated, and other experiments have also thrown a doubt upon the soundness of this theory.

CRYSTALLINE FORM.

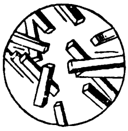
(185.) A great many of the soluble salts, and other soluble substances, *crystallize* when their solution is evaporated; that is, spontaneously collect into regular shapes. A very familiar instance of this is in sugar-candy, which is made by allowing a strong hot syrup to cool and evaporate; the form, in this instance, is an oblique rhombic prism. The student will notice the very different forms of different crystals. Common salt crystallizes in the form of a cube; alum that of an octohedron; saltpetre in a six-sided prism; Epsom salt in a four-sided prism. The more slowly the solution

Common Salt.



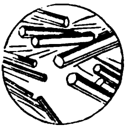
Cubes.

Epsom Salt.



Four-sided Prism.

Saltpetre.

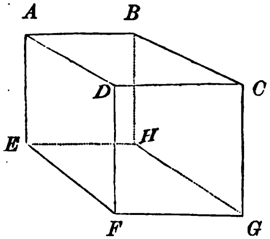


Six-sided Prism.

is evaporated, the larger and more regular are the crystals; something, too, depends on the bulk of the solution. Very beautiful crystals of saltpetre may be obtained from the manufactures; here the quantity of liquid is so great, that the solution takes many hours, or even days, to cool. Foul and muddy liquors give usually larger crystals than those that are clear.

(186.) CRYSTALLOGRAPHY* is a science by itself; we can only, therefore, give a mere outline of it here.

The surfaces or sides of the crystal are mostly flat, and are called the *planes* or *faces* of the crystals; the lines formed by the meeting of two faces, are called *edges*. The angles between any two planes are called the *plane angles*, and the points formed by the meeting of three planes, at least, are called the *solid angles*. Thus, in the cube here drawn;—the side A B C D is a face; the line A B formed by the meeting of the sides, is an edge; the angle D A E, formed by the meeting of the D A B C, B A E H, is a plane angle, which, in this case, is a right angle; the points A B C, &c., are solid angles.†



(187.) Sometimes an edge is replaced by a side, or a solid angle is truncated; thus, for example, by

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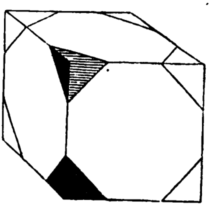
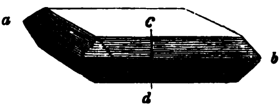
* Derived from two Greek words, meaning, the science of crystals.

† If the student is not familiar with the geometrical terms, he is recommended to procure the little book, published by the Society, in which these are explained.

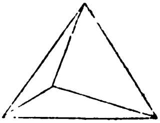


cutting off the points, or solid angles of a cube, a figure of the kind shown in the engraving will be produced, which, by continuing this process, will terminate in an octohedron. This process sometimes goes on in nature; for example, common salt, when crystallized out of a solution containing acid, crystallizes in octohedra.

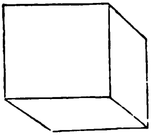
(188.) It will be found that crystals break more readily in some directions than others. This is shown in crystals of selenite, (which are easily procured out of the blue clay which is dug in sinking wells in London,) which peels off in flakes in the direction *a b*, but is fibrous and crumbly if it be attempted to be cut in the direction *c d*. The planes in which a crystal splits naturally, are called cleavage planes.



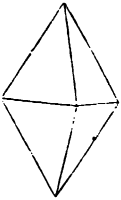
(189.) Very often, when a crystal is split, the fragments still retain the same form as the original crystal, so that it is sometimes possible to tell the nature of a fine powder, by examining it with a magnifier. Sometimes, however, we may obtain a different form from the primitive form of the crystal, by cleaving in particular directions; this is called the *secondary* form. Of course, if we start with a crystal of the secondary form, and consider that the primitive, we may obtain, possibly, that which before was considered the primitive form, which must then be considered as the secondary. Which form is to be considered the primary, is often a matter of convenience; when, however, several concur in giving one, that one is usually considered as the primitive, and the



Tetrahedron,
4 triangular faces.

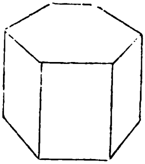


Cube,
6 square sides.

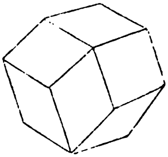


Octohedron,
8 equilateral triangulars.

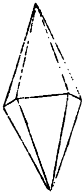
others as secondary forms. Amongst the principal primitive forms, are reckoned the cube, tetrahedron, octohedron, six and four-sided prism, and the rhombohedron.



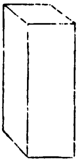
Hexahedral
Prism.



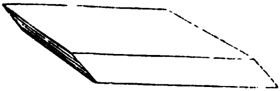
Rhomboidal Dodecahedron,
12 rhomboidal faces.



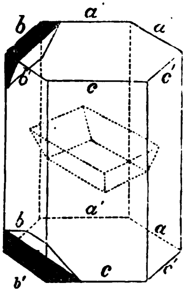
Triangular Dodecahedron, 12 triangular faces.



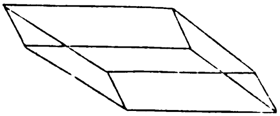
Four-sided
Prism.



Rhombohedron,
6 rhomboidal sides.



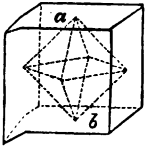
(190.) If we take a six-sided prism of calcareous spar, we can, with the help of a knife, and a smart blow, knock off the edges *a b c*, while *a' b' c'* will not yield to the blow. In the same way the edges of the base *a' b' c'*, opposite *a' b' c'* respectively, can be removed, while the edges *a b c* cannot. By going on in this way, the new faces will at last meet, and then we shall have an obtuse rhombohedron, which may have its sides pared away, still leaving it of the same shape, that is, all the sides or faces inclined at the same angle. There are several hundred different forms of crystals of calcareous spar, all of which, by following the natural cleavage of the crystals, may be dissected into rhombohedra, which is therefore considered as the primitive form. The shaded portion represents the part which is supposed to be cleft from the crystal. Crystals are distinguished, then, by their symmetry; that is, similar surfaces are distributed in a similar manner; and however the faces are altered, they are always altered so as to remain symmetrical.



(191.) The axes of symmetry are those lines in the crystal in reference to which every face is accompanied with other faces, having the same positions and properties. Thus the cube has three equal axes at right angles to each other, passing through the centres of the faces, as in fig. 1;

hence by the rule of symmetry stated above, if one face of a cube be modified in any manner, all the others must be modified in the same manner; and hence the modifications in those crystals which are of cubic form are few and simple, and are of perfect symmetry. Again, there may be two axes of equal symmetry, and a third not symmetrical, as in the case of the right-square prism; or there may be three axes all unequal, as in the case of the right prism with rectangular base. In all these cases the axes are at right-angles to each other; besides this, they may be, some or all of them, oblique. The following is a table of the different systems, according to Weiss and Mohs, as given in the valuable Introduction to Chemical Philosophy by Professor Daniel. *a b* is an axis of the crystal.

PHYSICAL CHARACTERS.	SYSTEMS.	ALLIED FORMS.	EXAMPLES.
1. Single Refraction .... Expansion equal in all directions.	1. CUBIC, OCTOHEDRAL, TESSULAR or REGULAR. 3 rectangular axes, all equal.	1. Cube. 2. Regular Octohedron. 3. Tetrahedron. 4. Rhombic Dodecahedron. 5. Trapezohedron.	Copper, Nickel, Gold, Alum, Common Salt, Arsenious Acid, Fluor Spar, and Iron Pyrites.
2. Double Refraction. Expansion not equal in all directions. One axis of no double refraction.	2. RIGHT SQUARE PRISMATIC. 3 rectangular axes, 2 equal.	6. Square Prism. 7. Octohedron, with a square base.	Idocrase, Anatase, Ferrocyanide of Potassium, and Bicyanide of Mercury.
Expansion equal in two directions at least.	3. RHOMBOHEDRIC. 3 equal axes, not rectangular; 1 perpendicular to the 3.	8. Rhombohedron. 9. Bipyramidal Dodecahedron. 10. Hexangular Prism.	Calcareous Spar, Nitrate of Soda, Ice, Tourmaline, Quartz, and Amethyst.
Two axes of no double refraction..	4. RIGHT, RECTANGULAR or RHOMBIC PRISMATIC. 3 rectangular axes, no two equal.	11 Right Rectangular Prism. 12. ——— Rhombic ditto. 13. ——— Rectangular Octohedron. 14. ——— Rhombic ditto.	Sulphate of Potash, Nitre, Rochelle Salt, Topaz, Arragonite, Bichromate of Potash, Citric Acid, Sulphate of Magnesia, and Sulphate of Zinc.
Expansion unequal in 3 directions.	5. OBLIQUE, RECTANGULAR or RHOMBIC PRISMATIC. 2 axes oblique, the third perpendicular to both.	15. Oblique Rectangular Prism. 16. ——— Rhombic ditto. 17. ——— Rectangular Octohedron. 18. ——— Rhombic ditto.	Feld Spar, Epidote, Carbonate of Soda, Glauber Salt, Sulphate of Iron, Chlorate of Potash, Borax, Sugar, Selenite, Acetate of Zinc, and Oxalic Acid.
	6. DOUBLY-OBLIQUE, PRISMATIC. 3 axes, all intersecting each other obliquely.	19. Doubly-oblique Prism. 20. ————Octohedron.	Axinite, Sulphate of Copper, Sulphate of Cinchonia, and Nitrate of Bismuth



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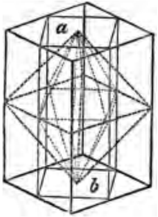

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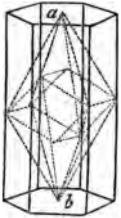

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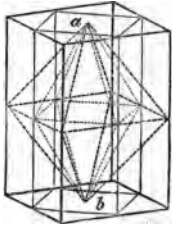

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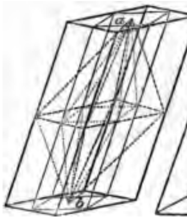

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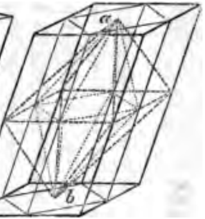


6.

(192.) **Dimorphism.**—Most minerals only crystallize in forms which may be reduced to one system. Some, however, are capable of assuming two forms, which belong to two different systems, and cannot be derived the one from the other: such a substance is sulphur; deposited from its solution in sulphuret of carbon, it crystallizes in octohedra with rhombic bases, but when melted and allowed to cool slowly, the centre of the mass crystallizes in oblique rhombic prisms. Carbon in the diamond crystallizes in octohedra, in graphite in six-sided plates; carbonate of lime, as calcareous spar, in rhombohedra; arragonite, in forms related to the rectangular octohedron; iron pyrites, in cubes and in an incompatible prismatic structure. The word dimorphous is derived from the Greek, and signifies "double-formed."

(193.) **Isomorphism.** — Certain substances to which a similar constitution is ascribed possess the remarkable property of exactly replacing each other in crystallized combinations, without altering the form and geometrical character of the crystals; such substances are said to be isomorphous, (another Greek word, signifying "equal-formed.")

Magnesia, the oxides of zinc, copper, nickel, and the *protoxide* of iron, for example, are isomorphous. The salts of these oxides, with the same acids, are not distinguishable by the eye when of the same colour.

In the same manner, alumina and *peroxide* of iron replace each other without change of crystalline form; so do potash, soda, and ammonia. Common alum is a sulphate of alumina and potash, but the alumina may be replaced by *peroxide* of iron, or the potash by soda or ammonia, and the figure of the crystals remains unchanged. There is much difficulty in obtaining the crystalline form of the elements; nevertheless, there is every reason to believe that the elements composing isomorphous substances are themselves isomorphous.

(194.) The following are the different isomorphous groups, as given in the reports of the Cavendish Society:—

I. Sulphur Class.—Sulphur, selenium, tellurium, oxygen. The first three exhibit the closest parallelism; the last has many properties in common with the others. Manganic acid is isomorphous with sulphuric acid; this connects these elements with the next class.

II. Magnesium Class.—Magnesium, calcium, manganese, iron, cobalt, nickel, zinc, cadmium, copper, hydrogen, chromium, aluminum, glucinum, vanadium, uranium, yttrium, thorium.

III. Barium Class.—Barium, strontium, lead.

IV. Potassium Class.—Potassium, ammonium, sodium, silver.

V. Chlorine Class.—Chlorine, iodine, bromine, fluorine.

VI. Phosphorus Class.—Nitrogen, phosphorus, arsenic, antimony, bismuth.

VII. Tin Class.—Tin, titanium.

VIII. Gold Class.—Isomorphous with silver in the metallic state.

IX. Platinum Class.—Platinum, iridium, osmium.

X. Tungsten Class.—Tungsten, molybdenum, tantalum, niobium, pelopium.

XI. Carbon Class.—Carbon, boron, silicon.

Unclassed.—Mercury; which is partly analogous to silver, and partly to copper; cerium, didymium, lanthanum, lithium, rhodium, ruthenium, palladium, and uranium.

CHAPTER V.

METALLIC SALTS.

POTASSIUM.—K 40.

(195.) THIS metal was discovered by Sir Humphry Davy, 1807, who obtained it by decomposing hydrate of potash with the galvanic battery.

Potassium may be better prepared by the following process. The crude tartar of commerce is heated to redness in a covered pot; the result is an intimate mixture of carbonate of potash and charcoal. This is quickly powdered and mixed with one-tenth of its weight of charcoal in small lumps, and the mixture put into an iron bottle, with a short and wide iron pipe fitted into its mouth; to this is attached a receiver of copper, kept cool with ice, and partly full of rock oil or Persian naphtha. The bottle is then raised to nearly a white heat, when the carbon decomposes the potash, carbonic oxide is given off, and potassium distils over, and falls in large drops into the rock oil. If the metal be required absolutely pure, it must be redistilled in an iron retort, from which the air has been expelled with vapour of naphtha.

(196.) **POTASSIUM** is a brilliant white metal, at common temperatures soft as wax, but at 32°, brittle and crystalline; it melts at 150°, and distils at a bright red heat: its density, or specific gravity, is .865, and it is the *lightest* known solid. It tarnishes instantly by exposure to the air, becoming covered with a crust of caustic potash; thrown upon water it floats, takes fire, and burns with a beautiful purple flame, yielding an alkaline solution. If a globule of potassium be put in a small tube filled with fine sand, and then immersed in water, that fluid will gradually rise through the sand, and, when it reaches the potassium, will be decomposed with such violence that the sand will be blown out, and the tube most probably broken. The vapour of potassium is of a green colour.

(197.) POTASSIUM AND OXYGEN. POTASH. POTASSA. PROTOXIDE OF POTASSIUM, KO, may be obtained by heating an equivalent of hydrate with an equivalent of potassium; 40 parts potassium being used to 57 of the hydrate, hydrogen is evolved, and two equivalents of anhydrous protoxide remain. It is hard, grey, and brittle, very alkaline. With water it forms a hydrate, which cannot be decomposed by heat. Its composition is—

	Atoms.	Weight.	per Cent.
Potassium	1	40	83.33
Oxygen	1	8	16 67
Anhydrous Potassium .	1	48	10C.00

(198.) HYDRATE OF POTASSA. CAUSTIC POTASH. KO, HO.—This substance may be procured by decomposing carbonate of potash, by boiling with lime. For this purpose, pure carbonate of potash should be boiled with half its weight of dry quicklime, with 8 or 10 parts of water, in a clean iron vessel. The water should be filled up as it boils away, and the solution be tested from time to time, till it ceases to effervesce on the addition of nitric acid. The solution should then be allowed to settle in a bright iron or silver vessel, poured off from the sediment, and evaporated, till it comes to an oily consistence, and concretes in cooling. Contact with air should be avoided as much as possible, or carbonic acid would be again absorbed. It is sometimes cast in the form of sticks, for the use of surgeons, who use it as a cautery.

Hydrate of potash consists of—

	Atoms.	Weight.	per Cent.
Potash	1	48	84.21
Water	1	9	15.79
Hydrate of Potash . .	1	57	100.00

Hydrate of potash is white and crystalline; specific gravity 1.7; it is very acrid and corrosive; fusible below redness, and rises in acrid fumes at a bright red heat. Touched by the fingers it feels soapy, and soon destroys the skin. It is highly alkaline, converting vegetable blues to green, and reddening turmeric paper; with fat oils it forms soap. It is very extensively used in the arts, and in medicine.

(199.) PEROXIDE OF POTASSIUM. KO^3. — When potassium is burned in air, or oxygen, a yellow fusible substance is procured, which on cooling acquires a scaly appearance; heated in hydrogen, it diminishes the bulk of the gas, and forms water; put into water, oxygen is evolved, and solution of potash obtained. It may also be formed by passing oxygen over red-hot potash.

(200.) CHLORIDE OF POTASSIUM. K Cl. —

Potassium burns in chlorine. This compound, formerly called muriate of potash, consists of—

	Atoms.	Weight.	per Cent.
Potassium	1	40	52.6
Chlorine	1	36	47.4
Chloride of Potassium .	1	76	100.0

Chloride of potassium dissolves, in 3 parts of water, at 60°. According to Gay Lussac, 100 parts of water at 32° dissolve 29.23 parts, and the water takes up 0.27 more of the salt, for every 1.8° above 32°. It produces cold by solution in water; it crystallizes in cubes; specific gravity 1.9; and is anhydrous. It is prepared from kelp, which is now valued principally for the iodide and chloride of potassium it contains.

(201.) CHLORATE OF POTASH, KO, ClO^5, is formed by passing excess of chlorine through a solution of potash: chloride of potassium and chlorate of potash are formed. The reaction is—

$$6\,KO + 6\,Cl = 5\,K\,Cl + KO\,ClO^5.$$

Chlorate of potassa is an anhydrous salt, crystallizing in tables of a pearly lustre belonging to the oblique prismatic system; specific gravity 1.989. It fuses between 400° and 500°, and at a higher temperature is resolved into chloride of potassium and oxygen; it is soluble in 18 parts of cold water, and 2.5 of boiling water; it is, therefore, easily separated from chloride of potassium by its inferior solubility. It is manufactured for the lucifer-match makers. When rubbed with sulphur in a mortar, it explodes violently; mixed with sulphur and charcoal, it forms a compound which explodes with a blow, and has been used to fill percussion caps; it has, however, the disadvantage of rusting the touch-hole: hence fulminating mercury is now substituted.

(202.) **Perchlorate of Potash**, KO, ClO^7, may be formed by heating the chlorate in nitric acid: 4 atoms of chlorate yield 1 of perchlorate. This salt resembles the chlorate, but is less soluble, requiring 65 times its weight of water, at 60°, for its solution.

(203.) **Iodide of Potassium.** KI.—This may be prepared by dissolving iodine in solution of potash, the action being analogous in every respect to that of chlorine; the mixture of iodide of potassium and iodate of potash which results may be entirely converted into iodide of potassium by heat. Iodide of potassium crystallizes in cubes: 100 parts of water dissolve 143 of the salt. It is not deliquescent, except in a very damp air.

(204.) **Iodate of Potash**, KO, IO^5, may be separated from a solution prepared as above, by evaporation. Iodate of potash requires 14 parts of water, at 60°, for its solution, and resembles the chlorate.

(205.) **Bromide of Potassium**, KBr, is a salt resembling the chloride, crystallizing in cubes, and soluble.

(206.) **Bromate of Potash**, KO, BrO^5, resembles chlorate of potash, and is prepared in a similar manner.

(207.) **Fluoride of Potassium**, KF, is formed by saturating potash with hydrofluoric acid. It is deliquescent, and difficultly crystallizable.

(208.) **Nitrate of Potash. Nitre. Saltpetre.** KO, NO^5.—This salt is found in the East

Indies, and imported to this country in small brown crystals, which contain common salt. Nitre crystallizes in six-sided prisms, with dihedral summits; its specific gravity is about 2.10; its primitive form is the rhombic prism. At 60° nitre dissolves in between 3 and 4 parts of water, and in one-third of its weight at 340°, which is the boiling point of a saturated solution. The solution of the salt in water produces cold. 1 part of nitre in 5 of water lowers the temperature from 50° to 35°. It consists of—

	Atoms.	Weight.	per Cent.
Potash	1	48	47.1
Nitric Acid	1	54	52.9
Nitrate of Potash . . .	1	102	100.0

(209.) *Purification of Nitre.*—The rough salt is dissolved in hot water, the scum is taken off, and the sand and insoluble impurities allowed to settle out; it is then pumped into square coolers, and the nitre crystallizes out, leaving in solution the greater portion of the saline impurities. If the nitre be not sufficiently pure, it is again dissolved in boiling water and recrystallized. The mother liquors still retain much nitre, they are therefore again boiled, when common salt separates, and is taken out of the liquor, which is again transferred to the coolers, when an impure nitre crystallizes out. This is considered as rough, and is again subjected to the same processes. In this way nearly the whole of the nitre is separated from the salt, which is then sold as a manure: the crystals are washed with cold water, and dried in kilns. The theory of this process is very simple: common salt, the chief impurity, is almost equally soluble in hot and cold water, while nitre is much more soluble in hot than cold water; hence we may get rid of salt by boiling: the salt (supposing both dissolved to saturation in the cold liquid) falls as the water boils away, until at length, when the nitre begins to fall with it, the liquid is allowed to cool, and nitre crystallizes out.

(210.) GUNPOWDER.—The chief demand for nitre is in the manufacture of gunpowder, and great care must be taken that the nitre to be used for this purpose contains no deliquescent salts, as otherwise the powder will get damp and spoil. The ingredients of gunpowder are—75 parts nitre, 15 charcoal, 10 sulphur; they are perfectly mixed, moistened, beaten into a cake, which is afterwards broken up, made into grains, and dried at 140° to 150°. The use of the sulphur is to inflame the gunpowder, as it kindles at a low temperature; it is, so to speak, the match which fires the nitre; the oxygen is transferred to the carbon, forming carbonic oxide; the sulphur combines with the potassium, and nitrogen is set free. Hence, a few grains of powder are suddenly expanded into a large volume of gas, which is still further expanded by the very high temperature produced by the combustion. This accounts for the enormous force produced in the explosion.

(211.) SULPHURETS OF POTASSIUM.—There are five sulphurets, containing respectively 1, 2, 3, 4, and 5 equivalents of sulphur.

The MONOSULPHURET may be formed by the action of charcoal on sulphate of potash. It is a crystalline reddish substance, and is a sulphur base; that is, it unites with sulphuretted hydrogen, bisulphuret of carbon, sulphuret of arsenic, and forms salts which are crystallizable, just as the corresponding compounds with oxygen do.

(212.) **Sulphate of Potash**, KO, SO^3, is largely prepared in the arts. Its taste is bitter and saline; it is not very soluble; 1 part requires 11½ parts of water for solution at 60°, and 4 at 212°; specific gravity 2.62. When sulphuric acid is added to a strong solution of potash, the sulphate is thrown down as a white granular powder. It crystallizes in a rhombic octohedron.

(213.) **Bisulphate of Potash**, $KO, 2SO^3$, is the residue obtained in the process for the manufacture of nitric acid. It is soluble, without decomposition, in one-half its weight of boiling water; with more water it is resolved into sulphate of potash and sulphuric acid.

(214.) **Carbonate of Potash**, KO, CO^2, is a salt of much importance. It is known in commerce under the names of woodash, potash, and pearlash. It is prepared for the purposes of commerce by lixiviating the ashes of vegetables. The English market is chiefly supplied from North America.

Carbonate of potash is fusible at a red heat; specific gravity 2.24; very soluble; deliquescent. 100 parts of water dissolve 90 parts at 60°, and 205 at 275°, which is the boiling point of a saturated solution. Its taste is alkaline. It consists of—

		Atoms.	Weight.	per Cent.
Anhydrous	Potash	1	48	68.6
	Carbonic Acid .	1	22	31.4
Carbonate of Potash		1	70	100.0

The crystals contain 2 equivalents of water.

(215.) **Bicarbonate of Potash**, $KO, 2CO^2 HO$ + or $KO, CO^2 + HO, CO^2$, is formed by passing carbonic acid into a solution of the carbonate. It is much less soluble than the carbonate, requiring 4 parts of water at 60°, and its own weight at 212°, for solution. Long boiling converts it into carbonate, with escape of carbonic acid; so does a red heat.

(216.) CYANIDE OF POTASSIUM, K, C^2N, or K, Cy, may be prepared by the combustion of potassium in cyanogen; or by passing pure nitrogen over a mixture of charcoal and carbonate of potash, heated to whiteness; or by exposing ferrocyanide of potassium to a bright red heat, in a covered vessel. The iron sinks to the bottom, and cyanide of potassium mixed with cyanate of potash may be poured off. It must be carefully preserved from contact with air, as it is very prone to absorb oxygen, and pass into cyanate of potash. It crystallizes in cubes; its taste is pungent and alkaline, and it is very poisonous. It is a powerful reducing agent.

(217.) CYANATE OF POTASH, KO, CyO, is obtained by heating a mixture of 4 parts of dry ferrocyanide of potassium with 1 of peroxide of manganese, to dull redness; the cyanate may then be dissolved out with spirit of wine, of specific gravity 0.86. It is decomposed by water and acids, which convert the cyanic acid into carbonic acid and ammonia.

(218.) SULPHOCYANIDE OF POTASSIUM may be prepared by exposing to nearly a red-heat a mixture of 5 parts of dry ferrocyanate of potash, 5 sulphur, 1 carbonate of potash, stirring as long as it continues to burn; lixiviating the residue in hot water, and precipitating the iron which still remains in solution with potash, filtering and crystallizing. It is a deliquescent salt, much resembling nitre in appearance.

(219.) FLUOSILICATE OF POTASH, KF, SiF^2, falls in the form of an iridescent jelly, when silico-fluoric acid is passed into a solution of potash. It consists of—

	Atoms.	Weight.	per Cent.
Potassium	1	40	45.71
Silicon	1	15	13.39
Fluorine	3	57	50.90
Silicofluoride of Potassium .	1	112	100.00

(220.) *General Character of the Salts of Potash.*—These are all soluble in water: the double chloride of potassium and platinum, the fluosilicate, and the bitartrate very sparingly so. Chloride of platinum produces a characteristic yellow precipitate; it is necessary, however, to be certain that the solution to be tested contains no ammoniacal salts, which also give a precipitate with the same reagent: their absence may be insured by giving the substance to be examined a red heat: the delicacy of this test is increased by the addition of alcohol. A strong solution of tartaric acid, added in excess, produces a precipitate of bitartrate: if the solution of the salt be weak, the precipitate forms slowly, but its formation is accelerated by stirring; it is entirely and readily redissolved on the addition of potash. Fluosilicic acid produces a gelatinous precipitate in solutions of potash. Heated before the blowpipe, or in the flame of a spirit-lamp, the salts of potash produce a characteristic purple tint.

SODIUM.—Na 24.

(221.) This metal was discovered by Sir Humphry Davy, by the same means as were used in the case of potassium.

SODIUM may best be obtained by a process analogous to that used for potassium. Six parts of carbonate of soda are dissolved in a little water, mixed with two parts fine charcoal, and one part in lumps. The whole is then evaporated to dryness, transferred to an iron bottle, heated to whiteness, and sodium distils over. It requires the same precautions for its preservation as potassium.

Sodium is a silver-white metal. Specific gravity, .972; melts at 194°; and does not become brittle at 32°. It is volatile at a white heat, and distils as a colourless vapour. It does not take fire when thrown upon water, unless its motion be restrained; with hot water it takes fire at once, and burns with a bright yellow flame, giving rise to a solution of soda.

(222.) There are two oxides of sodium: anhydrous soda, which is the protoxide, NaO, prepared as anhydrous potash, which it much resembles, but is less fusible; and peroxide, NO^3, which is yellowish green, and resembles the peroxide of potassium.

(223.) HYDRATE OF SODA. CAUSTIC SODA, NaO, HO, is prepared by decomposing a dilute solution of carbonate of soda with quicklime, as directed for potash.

The solid hydrate is a white fusible substance, specific gravity 2.0, resembling hydrate of potash; it is deliquescent, and absorbs carbonic acid. It is extensively used in the arts, for making soap. Soda is not quite so powerful a base as potash.

Its composition is—

	Atoms.	Weight.	per Cent.
Sodium	1	24	75
Oxygen	1	8	25
Anhydrous Soda .	1	32	100

Hydrate,

	Atoms.	Weight.	per Cent.
Soda	1	32	78.1
Water	1	9	21.9
Hydrate of Soda .	1	41	100.0

(224.) CHLORIDE OF SODIUM. SEA SALT. MURIATE OF SODA. $NaCl$. — Sodium burns in chlorine, and produces this compound, which consists of—

	Atoms.	Weight.	per Cent.
Sodium	1	24	40
Chlorine	1	36	60
Common Salt . .	1	60	100

The great source of chloride of sodium is the ocean. It exists also in large beds of what is called rock-salt. Small quantities exist in most river and spring waters.

When heated, chloride of sodium falls to pieces with a crackling noise, or *decrepitates*, as it is called; at a red heat it fuses; at a bright red it sublimes. 100 parts of water at 60°, dissolve 37 of salt; and it is nearly equally soluble in hot and cold water. The ice which forms in sea water is destitute of salt. It crystallizes in cubes, which are not deliquescent when pure: specific gravity, 1.25. Mixed with snow, the thermometer sinks to 0, and the snow melts. This property of chloride of sodium is often made use of to clear snow off a pavement; it should not be employed, as the excessive cold to the feet may prove dangerous.

It is used for preserving food, as a source of soda, and as a manure; and is of the utmost commercial importance.

(225.) CHLORIDE OF SODA is used as a disinfectant. It is made by passing chlorine into carbonate of soda; and is sold as Labaraque's disinfecting soda liquid; it is essentially hypochlorite of soda.

(226.) CHLORATE OF SODA, NaO, ClO^5, may be procured as directed for chlorate of potash; but in consequence of its not being less soluble than the chloride, the salts are with difficulty separable.

(227.) PERCHLORATE OF SODA, NaO, ClO^7, is deliquescent; in other respects it resembles perchlorate of potash.

(228.) IODIDE OF SODIUM, NaI, is contained in the mother liquors of kelp; it crystallizes in cubes. 100 parts of water at 60° dissolve 173 of iodide.

(229.) FLUORIDE OF SODIUM, NaF, crystallizes in cubic crystals; 100 parts of water dissolving 4 of this salt.

(230.) NITRATE OF SODA. CUBIC NITRE, NaO, NO^5, is an abundant natural product of Peru; it crystallizes in rhombohedra, which are deliquescent in damp air; it may be used in the manufacture of nitric and sulphuric acids, but cannot be employed in gunpowder, as it burns too slowly, and absorbs moisture.

(231.) SULPHUR AND SODIUM. What has been said with regard to sulphur and potash, applies equally to soda.

SULPHURET OF SODIUM, Na S, is prepared in the arts by decomposing the sulphate with charcoal.

(232.) **HYPOSULPHITE OF SODA.** NaO, S^2O^2.—This salt is used for photographic purposes; the best method of preparing it is to pass sulphurous acid, which has been well washed, through a strong solution of carbonate of soda. The resulting solution of sulphite of soda is then digested with sulphur, for several days, at a gentle heat; by careful evaporation, the salt is obtained in large crystals, which are very soluble.

(233.) **SULPHATE OF SODA. GLAUBER SALT**, NaO, SO^3, is abundantly produced in many processes of the arts. Vast quantities of it are produced by the decomposition of common salt with sulphuric acid. The reaction is,

$$NaCl + SO^3, HO = NaO, SO^3 + HCl.$$

It crystallizes in a figure derived from the oblique rhombic prism; the crystals contain 10 equivalents of water, and in dry air effloresce, parting with the whole of their water of crystallization. 100 parts of water at 60 dissolve 11 of anhydrous, 31 of crystallized salt; and the solubility increases up to 91½°, at which temperature 100 parts of water dissolve 5 of anhydrous, 322 of crystallized salt; heated beyond this point the solubility diminishes; and evaporated at a higher temperature, the solution deposits anhydrous opaque prismatic crystals. The salt is bitter and purgative, and exists in the Cheltenham water.

(234.) **BISULPHATE OF SODA**, $NaO\,2\,SO^3$, is obtained by adding sulphuric acid to a warm solution of soda, evaporating to dryness, and heating short of redness; it is very soluble, and has an acid reaction; when strongly heated, the fused salt gives up anhydrous sulphuric acid, and is a convenient method of preparing that substance when Nordhausen sulphuric acid is not at hand.

(235.) **Phosphates of Soda.** **Tribasic Phosphate of Soda**, $NaO, HO, PO^5 + 24 HO$, is prepared by neutralizing phosphoric acid or bone earth, with slight excess of carbonate of soda; it crystallizes in oblique rhombic prisms, which are efflorescent; it dissolves in 4 parts of cold water. By adding solution of caustic soda to the above, $3 NaO, PO^5 + 24 HO$, is obtained, sometimes called subphosphate. The crystals are slender six-sided prisms. Both this and the above have an alkaline reaction.

$NaO 2 HO, PO^5 + 2 HO$ may be obtained by adding phosphoric acid to the first described salt, till it ceases to precipitate chloride of barium. By exposure to cold its form becomes prismatic; it is very soluble.

(236.) **Microcosmic Salt.** **Tribasic Phosphate of Soda, Ammonia and Water.** $NaO, NH^4O, HO, PO^5 + 8 HO$.—Six parts of common phosphate are heated with 2 of water till the whole is liquefied, when 1 part of powdered sal ammoniac is added; common salt separates; the solution is then filtered and crystallized. It is very soluble; when gently heated it parts with the water of crystallization; and at a higher temperature with the water and the ammonia; metaphosphate of soda remaining, which is very fusible, and a useful flux in blowpipe experiments.

(237.) **Bibasic Phosphate of Soda.** **Pyrophosphate of Soda**, $2 NaO, PO^5 + 10 HO$, is prepared by heating strongly the common phosphate, dissolving in water, and recrystallizing. The crystals are very brilliant, permanent, and less soluble than the common phosphate.

(238.) MONOBASIC PHOSPHATE OF SODA. METAPHOSPHATE OF SODA, NaO, PO^5, is obtained by heating microcosmic salt. It is a transparent glassy substance: fusible at a dull red heat; deliquescent, and uncrystallizable.

The tribasic phosphates give a yellow, the bibasic and monobasic, white, precipitates, with a soluble salt of silver.

(239.) CARBONATE OF SODA. NaO, CO^2.—This was formerly prepared by the combustion of marine plants; it is now, however, manufactured from sea-salt. The following is a sketch of the process; for the details of which, the student is referred to the little book, on the Sulphuric Acid, Soda and Soap Manufacture, published by the Society for Promoting Christian Knowledge.

Sulphate of soda is prepared by decomposing common salt with sulphuric acid. The sulphate of soda is ground up with an equal weight of charcoal and half its weight of coal-dust, and exposed to a strong heat in a reverberatory furnace, well stirred and raked out into an iron trough; in this state it is called, ball soda,. or British barilla. This is broken up, placed in vats, and covered with warm water; which after six hours is drawn off and evaporated to dryness; it is further purified by heating it again, with one-fourth its weight of sawdust, to dull redness. This is then dissolved in water, and crystallized.

In this process the sulphate is converted by the coal into sulphuret, which is decomposed by the lime, giving rise to soda and sulphuret of calcium, which again forms an insoluble substance with another portion of the lime. Were it not for this last, apparently trifling circumstance, the process would not be successful; for, on dissolving, there would again be an interchange, and the soda would revert to sulphuret of sodium, and the sulphuret of calcium to lime.

The ordinary crystals of carbonate of soda contain 10 equivalents of water, and are related in form to the oblique rhombic prism; specific gravity 1.26; they effloresce, crumbling to a white powder; heated, they fuse in their water of crystallization. The common crystals dissolve in 2 parts of cold and less than their own weight of boiling water.

(240.) BICARBONATE OF SODA, $NaO\ CO^2 + HO\ CO^2$, may be prepared by passing carbonic acid gas into a cold solution of the carbonate. It is a crystalline white powder which cannot be redissolved without partial decomposition; it requires 10 parts of water for solution at 60°; it is, therefore, much less soluble than the neutral carbonate; it is decomposed into the neutral carbonate by heat.

(241.) BIBORATE OF SODA. BORAX. $NaO, 2BO^3 + 10\,HO$.—This compound occurs native in Thibet and Persia. It crystallizes in six-sided prisms, which are efflorescent; it requires 12 parts of cold and 2 of boiling water for its solution. At a high temperature it parts with the whole of its water of crystallization, and fuses into a sort of glass. It is used in soldering, and glazing earthenware.

(242.) NEUTRAL BORATE, $NaO, BO^3 + 8\,HO$, may be obtained by fusing borax with carbonate of soda in equivalent proportions and dissolving in water.

(243.) There is a fluid alloy of 3 parts sodium and 1 potassium; equal parts form a crystalline brittle alloy.

(244.) *General Characters of the Salts of Sodium.*—These are all, without exception, soluble in water, and give no precipitate either with fluosilicic acid or chloride of platinum. Antimoniate of potash produces a precipitate, provided carbonate of potash be not present; it is not a very decisive test. They tinge the flame of the spirit-lamp or blow-pipe yellow.

AMMONIUM.—NH^4 18.

(245.) Of course, the substance ammonium being hypothetical, we cannot describe its properties. The student will bear in mind, that, by the salts of the oxide of ammonium, we mean salts of ammonia containing one equivalent of water essential to their constitution.

(246.) **Chloride of Ammonium. Hydrochlorate of Ammonia. Muriate of Ammonia. Sal ammoniac.** NH^4Cl.—This salt was originally obtained from Egypt, having been extracted from the soot of camels' dung. It is now largely manufactured by neutralizing the ammoniacal liquors of the gas-works with hydrochloric acid and purifying by sublimation.

Sublimed sal ammoniac is fibrous, tough, and difficult to powder. Specific gravity 1.45. It separates from water in cubic crystals or octohedra; it has a sharp saline state, is soluble in 2¾ cold, and a much smaller quantity of hot water; it sublimes without decomposition and is anhydrous.

(247.) **Nitrate of Ammonia,** NH^4O, NO^5, is prepared by neutralizing ammonia with dilute nitric acid; it crystallizes in prisms like nitre, specific gravity 1.7, dissolves in 2 parts of cold water, is feebly deliquescent, and deflagrates like nitre on heating with combustibles.

(248.) **Sulphate of Ammonia,** NH^4O, SO^3, *is prepared* by neutralizing gas liquor with sulphuric acid, and purifying by crystallization. It is soluble in 2 parts of cold water, and crystallizes in long flattened six-sided prisms, which lose an equivalent of water when heated. It is entirely decomposed by a strong heat.

(249.) SESQUICARBONATE OF AMMONIA. $2(NH^4O)3CO^2, + 2HO$.—This is known as smelling salts, and is prepared by heating together a mixture of sal ammoniac or sulphate of ammonia and chalk. It resolves itself spontaneously into neutral anhydrous carbonate and bicarbonate of ammonia.

(250.) BICARBONATE OF AMMONIA, $HO, CO^2 + NH^4O, CO^2$, is formed by passing carbonic acid into sesquicarbonate of ammonia. It is permanent, nearly tasteless, and inodorous and volatile; it resembles bicarbonate of potash.

(251.) SULPHURETS OF AMMONIA.—Several of these exist, but the most valuable is the double sulphuret of ammonia and hydrogen, commonly called HYDROSULPHATE OF AMMONIA. $NH^4S + HS$. It is obtained by saturating ammonia with sulphuretted hydrogen till no more is absorbed; the solution is nearly colourless at first, but afterwards becomes yellow; it must not be exposed to air. It gives precipitates with many metallic solutions, which are, for the most part, characteristic.

THE AMIDES.

(252.) The anhydrous acids combine with dry ammonia, forming saline compounds very different to the ordinary salts.

(253.) NEUTRAL CARBONATE OF AMMONIA. CARBAMIDE. NH^3, CO^2.—This compound is formed when one measure of dry carbonic acid and two of ammonia are passed through a cooled tube. It is a strongly alkaline white solid volatile at 140°. If water be present, other compounds are formed.

(254.) **Sulphimide**, NH^3, SO^2, is produced as above, with sulphurous acid instead of carbonic. It differs from sulphite of ammonia.

(255.) **Sulphamide**, NH^3, SO^3, is made by passing ammonia into a vessel lined with anhydrous sulphuric acid. It has a totally different form to sulphate of ammonia, nor are sulphuric acid and ammonia discoverable by the usual tests. On standing it gradually turns to sulphate.

(256.) **Amidogen.**—When potassium is heated in ammoniacal gas, hydrogen is set free, and an olive-green crystalline substance which is supposed to contain NH^2. It is thought that ammonia may be a hydruret of amidogen, as NH^2 has been called, analogous to water, and capable like it of uniting with acids.

LITHIUM.—L 7.

(257.) This metal is only found in some few rare minerals, pelalite, spodumene, and lepidolite. It is obtained by decomposing lithia with the galvanic battery, and resembles sodium.

(258.) **Lithia**, LO, may be obtained by heating finely-powdered pelalite with 6 times its weight of pure lime to whiteness in a platina crucible. The whole is then digested in hydrochloric acid, and filtered to get rid of silica; the solution is then mixed with carbonate of ammonia, boiled, and filtered, the clear liquor evaporated to dryness, heated to expel the sal ammoniac; the residue is wetted with oil of vitriol, evaporated to dryness and heated; fused sulphate of lithia remains.

(259.) Salts of Lithia.—

Salt.	Symbol.	Form.	Solubility.	Preparation.
Chloride....	$L\,Cl$......	Cubes	Deliquescent.	Neutralizing lithia, with $H\,Cl$.
Fluoride....	$L\,F$	Small opaque ...	Difficultly soluble	Do. with hydrofluoric acid.
Nitrate......	LO, NO^5	Rhombic prisms	Deliquescent.	Do. with nitric.
Sulphate ...	LO, SO^3	Rhombic prisms	Efflorescent...	Do. with sulphuric.
Carbonate..	LO, CO^2	Small prisms ...	Very sparingly soluble...	Carbonate of ammonia, and sulphate of lithia.

The salts of lithia tinge the flame of the spirit-lamp red.

CALCIUM.—Ca 20.

(260.) Calcium is produced by passing potassium in vapour over lime heated to whiteness, the reduced calcium is dissolved in quicksilver, and the amalgam distilled in a green glass retort. It is silver-white and extremely oxidizable.

(261.) Protoxide of Calcium. Lime. $Ca\,O$.—It may be obtained nearly pure by exposing white marble to a high heat for about an hour in an open crucible; if it be required absolutely pure, it must be obtained by heating an artificial carbonate prepared by precipitating the nitrate with carbonate of ammonia.

Pure lime is white or pale grey, acrid, caustic, and alkaline to tests; specific gravity 3; very difficult to fuse. In the flame of the oxyhydrogen blowpipe, a small portion is volatilized; it is these solid particles of white hot lime which give the flame its luminousness. Exposed to air, it absorbs water and carbonic acid. It is extensively employed as a manure; but if used for the destruction of vermin, it should be ploughed into the soil when quick, otherwise it has little more effect than chalk would have under the same circumstances. It is very useful in drying certain gases, and is of the greatest value in the arts. It consists of—

	Atoms.	Weight.	per Cent.
Calcium	1	20	71.43
Oxygen	1	8	28.57
Lime	1	28	100.00

(262.) HYDRATE OF LIME. SLACKED LIME. CaO, HO.—When water is poured on quicklime, great heat is evolved, and a bulky white powder is obtained, which is the hydrate. The heat generated in the slacking of lime is sufficient to char wood and inflame gunpowder, and must therefore exceed 500°. It may be obtained in imperfect crystals, under the air-pump. It consists of—

	Atoms.	Weight.	per Cent.
Lime	1	28	75.7
Water	1	9	24.3
Hydrate of Lime . .	1	37	100.0

LIME-WATER.—Hydrate of lime is more soluble in cold than hot water. At 32° 1 part of lime dissolves in 656 parts of water; at 60°, in 750; and at 212°, 1,280 parts. The solution is kept in the laboratory, and may best be prepared by pouring hot water on lime, and allowing the mixture to cool and settle. Its taste is strongly alkaline; it powerfully reddens turmeric paper, and changes the blue of violets to green; exposed to the air it absorbs carbonic acid.

Milk of lime is the hydrate mechanically suspended in water.

(263.) CHLORIDE OF CALCIUM. MURIATE OF LIME. Ca Cl. — This may be formed by dissolving chalk, or white marble, in hydrochloric acid. It has a strong attraction for water, and deliquesces; hence fused chloride of calcium is frequently used to deprive certain gases of aqueous vapour. One part of water at 60° dissolves 4 parts, and boiling water almost any quantity. It consists of—

	Atoms.	Weight.	per Cent.
Calcium	1	20	35.7
Chlorine	1	36	64.3
	1	56	100.0

Hydrated chloride, containing two equivalents of water, is made by evaporating till the solution becomes like thick syrup, when a crystalline mass concretes in cooling. In this state, if mixed with two-thirds of its weight of snow, it lowers the thermometer to 50° below 0.

Chloride of calcium absorbs ammonia, swells, cracks, and crumbles into a white powder.

(264.) CHLORIDE OF LIME. BLEACHING POWDER is made by passing chlorine into chambers containing hydrate of lime: the gas is absorbed, care being taken to keep the whole apparatus cool. It is a dry white powder, smelling feebly of chlorine. Exposed to air it absorbs carbonic acid, and gives off chlorine; heated, it gives off oxygen, and chloride of calcium is formed. It consists of a mixture of hypochlorate of lime, with variable proportions of hydrate of lime. The usual bleaching powder, when carefully prepared, consists of—

	Atoms.	Weight.	per Cent.
Chlorine	1	36	32.72
Hydrate of Lime .	2	74	67.28
	1	110	100.00

(265.) **Chlorate of Lime**, CaO, ClO_5, is a soluble deliquescent salt, crystallizing in oblique rhombic prisms. It is best formed by saturating chloric acid with chalk.

(266.) **Fluoride of Calcium, Fluor Spar**, CaF, is found native in Derbyshire, and called by the miners "Blue John." It is usually found in cubic crystals, which cleave into octohedra and tetrahedra. It is insoluble; it is not decomposed by cold sulphuric acid, but hydrofluoric acid is given off at 100°. It consists of—

	Atoms.	Weight.	per Cent.
Calcium	1	20	51.54
Fluorine	1	19	48.46
	1	39	100.00

Some specimens of native fluor spar become phosphorescent with heat.

Nitrate of Lime, CaO, NO^5, is a deliquescent salt, which crystallizes in acicular crystals.

(267.) **Sulphuret of Calcium.**—There are several, but none of them are of any commercial importance.

(268.) **Sulphate of Lime**, $CaO\ SO^3$, is an abundant natural product. It requires 500 parts of water for its solution at 60°, and rather less at 212°: being much more soluble than lime, lime-water gives no precipitate with sulphuric acid. Nearly all river and spring waters contain this salt, which makes them *hard*. It is decomposed by carbonate of potash, soda, and ammonia. It is found crystallized, and then contains two equivalents of water. It is known as selenite, gypsum, &c. It is the principal ingredient in plaster of Paris; the hydrate, on being exposed to a heat short of 500°, loses water, and crumbles into a white powder, which sets, on the addition of water, into a cake, from the formation of the hydrate: it is much used for taking casts, and in the finer kinds of mortar. It consists of—

	Atoms.	Weight.	per Cent.
Lime	1	28	41.2
Sulphuric Acid	1	40	58.8
Anhydrous Sulphate of Lime	1	68	100.0
Sulphate of Lime	1	68	79
Water	2	18	21
Crystallized Sulphate of Lime	1	86	100

The primitive form of selenite is a rhomboidal prism. The beautiful substance alabaster is also sulphate of lime.

(269.) Phosphuret of Calcium, CaP, is formed by passing vapour of phosphorus over lime. Care must be taken that the heat be neither too high nor too low; it should be a little short of redness. It is a brown substance, which gives out a nauseous garlic odour when breathed on.

(270.) Phosphates of Lime. — There are several; the following are the most important:—

Common Phosphate of Lime, Bone Phosphate, $8\,CaO,\ 3PO^5$.—This salt occurs abundantly in bone earth. It is decomposed by sulphuric acid, if a sufficient quantity be used, with the evolution of free phosphoric acid; if a smaller quantity, an acid phosphate of lime is formed. Hydrochloric and nitric acids dissolve it; so do acetic and carbonic acid.

Phosphate of lime is found native, associated usually with fluoride of calcium, in apatite, moroxite, phosphorite, and asparagus stone. Fossil bones also contain it; and coprolites, which are the fossil dung of reptiles. These bid fair to become an important manure.

Tribasic Phosphate of Lime and Water, $2\,CaO, HO\,PO^5+3\,HO$, may be prepared by adding common phosphate of soda, not in excess, to chloride of calcium. It occurs in small acicular crystals; it is insoluble in water, but is sometimes found dissolved by carbonic acid in mineral waters; it is soluble in dilute acids.

Bibasic Phosphate of Lime, $2\,CaO, PO^5$, and Monobasic Phosphate, CaO, PO^5, exist; the latter is formed when 2 equivalents of sulphuric acid are added to one of bone phosphate, and heated. This salt is the source of phosphorus in the arts.

(271.) Carbonate of Lime. CaO, CO^2.—Chalk, marble, limestone, are all carbonates of lime, more or less pure. It is an essential ingredient in almost all soils, and is very abundant. It consists of—

	Atoms.	Weight.	per Cent.
Lime	1	28	56
Carbonic Acid	1	22	44
	1	50	100

It is quite insoluble in water, but dissolves in that which contains carbonic acid; hence it is often precipitated from water on boiling, and forms a sort of stony deposit on the vessels used for heating the water, known as "fur." It is often very difficult to obtain water in limestone districts, which is fit to be used in steam boilers, in consequence of its tendency to produce fur.

Native carbonate of lime occurs crystallized in obtuse rhomboids, termed Iceland Spar, which is powerfully doubly refractive. Carbonate of lime is deposited from the petrifying well at Matlock, in whose waters it is dissolved by excess of carbonic acid.

Lime-burning.—Limestone or chalk is used to burn into quicklime. The other varieties of carbonate of lime crumble down into powder, and cannot be withdrawn from the fuel. The kiln used in this country is cup-shaped, made of masonry, with a grate at the bottom, above which is a door; the fuel and limestone are put in in alternate layers, the whole is kindled, and the lumps of chalk gradually descend to the bottom, as the fuel burns away, and are *quick* by the time they arrive at the bottom of the kiln. They still retain their shape, and may be carted away. Lime cannot be burned in close vessels; the presence of moisture is absolutely essential to the success of the process; so much so, that it is said that in cold dry weather the lime burns with difficulty, and that water introduced into the kiln, in the state of steam, facilitates the process.

(272.) *General Characters of the Salts of Lime.*—They are, when soluble, precipitated by the alkaline carbonates, and by potash and soda, but not ammonia. Oxalate of ammonia is a most delicate test for lime, and will detect 1 part of lime in 50,000 of water.

BARIUM.—Ba 69.

(273.) Barium is prepared as calcium. It is of an iron grey colour. Specific gravity about 2.00.

(274.) OXIDE OF BARIUM, BARYTA, BaO, is obtained by exposing nitrate of baryta to a red heat; or by exposing the carbonate, mixed with charcoal, to a white heat. Its specific gravity is about 4, being the heaviest of all the earths; hence its name, derived from Greek, and meaning heavy. It is a protoxide, and consists of—

	Atoms.	Weight.	per Cent.
Barium	1	69	89.6
Oxygen	1	8	10.4
Baryta	1	77	100.0

Hydrate of baryta, BaO, HO, is prepared as hydrate of lime; it dissolves in 20 parts of cold, and 3 of boiling water, and the solution is a most delicate test for carbonic acid. Baryta-water is powerfully alkaline and poisonous.

(275.) PEROXIDE OF BARIUM, BaO^2, is made when dry oxygen is passed over baryta at a red heat; put into water it forms an insoluble hydrate, containing 6 equivalents of water.

(276.) CHLORIDE OF BARIUM, $BaCl$, may be prepared by neutralizing carbonate of baryta with hydrochloric acid, or by heating equal parts of powdered sulphate of baryta and chloride of calcium to a red heat in a covered crucible; double decomposition takes place, and the chloride of barium must be washed out as rapidly as possible with boiling water, in order that the sulphate of lime may not again act on the chloride of barium. It is greyish; specific gravity 3.8; 100 parts of water dissolve 43 of the salt at 60°, and 78 at 222°. It consists of—

	Atoms.	Weight.	per Cent.
Barium	1	69	65.7
Chlorine	1	36	34.3
Chloride of Barium .	1	105	100.0

(277.) CHLORATE OF BARYTA, BaO, ClO_5, may be prepared as directed for chlorate of potash, though the salts are of similar solubility, and cannot therefore easily be separated; it is useful in preparing chloric acid.

(278.) NITRATE OF BARYTA, BaO, NO^5, may be produced by dissolving the carbonate in nitric acid, or by decomposing sulphuret of barium with nitric acid; it is soluble in 12 parts cold, or 4 of boiling water, and crystallizes in octohedra; it is, as well as chloride of barium, kept in the laboratory as a test for sulphuric acid. It consists of—

	Atoms.	Weight.	per Cent.
Baryta.	1	77	58.7
Nitric Acid	1	54	41.3
Nitrate of Baryta . .	1	131	100.0

(279.) SULPHURET OF BARIUM, BaS, may be prepared by heating sulphate of baryta white hot with charcoal; it is readily soluble in hot water, and the solution, on cooling, deposits hydrated crystals.

(280.) SULPHATE OF BARYTA, BaO, SO^3, is a natural product, insoluble in hot and cold water, and it therefore precipitates whenever sulphuric acid is added to a soluble salt of baryta; it is hence a very delicate test for that acid; it is anhydrous, and composed of—

	Atoms.	Weight.	per Cent.
Baryta	1	77	65.8
Sulphuric Acid. . .	1	40	34.2
Sulphate of Baryta .	1	117	100.0

The native sulphate of baryta is known as heavy spar and baroselenite. In Derbyshire a variety is found called "cawk;" its primitive form is a rhomboidal prism. When sulphate of baryta is boiled with carbonate of potash or soda, a portion of the sulphate is decomposed; the decomposition is never entire.

(281.) CARBONATE OF BARYTA, BaO, CO^2.—This salt falls whenever a soluble salt of baryta is added to an alkaline carbonate, as a white powder. It occurs native in witherite; it is poisonous. The remedy in this case is a soluble sulphate, as Glauber or Epsom salts. It may be used with great advantage for poisoning rats, as in case of its accidentally being administered a remedy is certain, which is not the case with arsenic. Should it be administered with a criminal intent, detection, as with arsenic, is almost a matter of certainty.

(282.) *General Characters of the Baryta Salts.*—The soluble salts furnish precipitates with carbonate and sulphate of soda. They also give a precipitate with a saturated aqueous solution of sulphate of strontia. All the barytic salts, except the sulphate, are soluble in dilute nitric or hydrochloric acid. Its principal use is as a test for sulphuric acid.

STRONTIUM.—Sr 44.

(283.) This metal derives its name from Strontian, in Argyleshire; it resembles barium.

(284.) PROTOXIDE OF STRONTIUM. STRONTIA, $Sr O$, may be obtained from the nitrate as directed for baryta; specific gravity, 3.9.

HYDRATE OF STRONTIA, $Sr O, HO$, is prepared as hydrate of baryta; it is soluble in 160 parts of water at 60°.

(285.) SALTS OF STRONTIA.—

Salt.	Symbol.	Form.	Solubility.	Preparation.
Chloride..	$SrCl$	Six-sided prisms ...	Deliquescent; $\frac{3}{4}$ its weight at 60	As directed for baryta.
Nitrate ...	SrO, NO^5	Octohedra...	5 parts at 60	Ditto
Sulphate .	SrO, SO^3	Powder	3,840 of boiling water	Native.
Carbonate	SrO, CO^2	Powder	1,536 of boiling water	Native.

(286.) *General Characters of the Salts of Strontia.*—These much resemble the salts of baryta, but are not poisonous; they are also more soluble. This earth may be distinguished from baryta by the following test:—Dissolve in hydrochloric acid, add sulphate of soda in excess, filter; test the clear liquid by carbonate of potash; if a precipitate fall, the earth is strontia; if none, baryta. (*Brande.*)

MAGNESIUM.—Mg 12.

(287.) This metal was discovered by Davy in the same manner as potassium. The best method of preparation is as follows:—Chloride of magnesium is prepared; this is then introduced into a tube of hard glass, with a few globules of sodium at the bottom; the heat of the spirit-lamp is then applied, when violent reaction takes place, chloride of sodium is formed, and magnesium set free. When cold, the contents may be put into water, by which the salt is dissolved out. It is a white malleable metal, fusible at a red heat, not acted on by water; heated in air, it burns into magnesia.

(288.) MAGNESIA. CALCINED MAGNESIA, MgO, is procured by exposing carbonate of magnesia to a red heat. It forms a soft white powder, which slowly attracts moisture and carbonic acid from the air. It unites quickly with water, forming a hydrate, which possesses a feeble degree of solubility, requiring 5,000 parts of water at 60°, and 36,000 parts at 212°. It is scarcely alkaline to test paper.

(289.) CHLORIDE OF MAGNESIUM, $Mg\,Cl$.—Mix a solution of chloride of magnesium with a solution of sal ammoniac, containing an equal quantity of chlorine; evaporate to dryness, and expose to a low red heat. Sal ammoniac sublimes, leaving chloride of magnesium in a fused state. The chloride cannot be prepared by neutralizing magnesia with hydrochloric acid, and evaporating, as the hydrochloric acid is expelled, and magnesia remains. When exposed to the air in a melted state, chlorine is given out and magnesia formed.

(290.) SULPHATE OF MAGNESIA. EPSOM SALT, $Mg\,O, S\,O^3, +7\,H\,O$.—This salt occurs in sea-water, and in many mineral springs; it is prepared by acting on magnesian limestone with sulphuric acid, and filtering out the sparingly soluble sulphate of lime. The crystals are derived from a rhombic prism; are soluble in their own weight of water at 60°, and in a less quantity at 212°. The salt has a nauseous bitter taste, and is purgative. Specific gravity, 1.7. It forms double salts with the sulphates of potash and ammonia.

(291.) CARBONATE OF MAGNESIA. MAGNESIA ALBA.—This term is generally applied to the white precipitate obtained by adding carbonate of soda or potash to a solution of sulphate of magnesia. It is a bulky light powder, and contains—

	Atoms.	Weight.	per Cent.
Magnesia	5	100	41.32
Carbonic Acid . .	4	88	36.36
Water	6	54	22.32
Magnesia alba . .	**1**	**242**	**100.00**

A neutral carbonate, MgO, CO^2, occurs native.

(292.) PHOSPHATE OF MAGNESIA, $2 MgO HO PO^5 + 14 HO$, separates when solutions of phosphate of soda and sulphate of magnesia are mixed, in small colourless prismatic crystals; it is soluble in 1,000 parts of water.

(293.) PHOSPHATE OF MAGNESIA AND AMMONIA, $2 MgO, NH^4O, PO^5 + 12 HO$.—When a soluble phosphate is mixed with a salt of magnesia, the above subsides immediately if the solution be strong; if very dilute, its precipitation is promoted by stirring. It is sparingly soluble in water, but not so in some saline solutions. Heated, it is resolved into bibasic phosphate of magnesia, containing 36.68 per cent. of magnesia. It consists of—

	Atoms.	Weight.	per Cent.
Ammonia	1	17	6.91
Magnesia	2	40	16.26
Phosphoric Acid . .	1	72	29.26
Water	12	117	47.57
	1	246	100.00

This salt is used to separate magnesia from its solutions. The liquid, previously freed from lime and alumina, &c., is mixed with phosphate of soda and excess of ammonia. The precipitate is collected, washed with a dilute solution of sal ammoniac, dried, and heated to redness, and weighed; 16.26 parts in 100 are magnesia. It exists in grain, and may be discovered in beer, derived from the barley.

(294.) *General Character of the Salts of Magnesia.*—They are usually colourless, and are recognised by the following characters:—

A glutinous white precipitate with caustic alkalies, insoluble in excess of precipitant, but soluble in sal ammoniac.

White precipitates with carbonate of soda and potash, but none with ammonia.

White crystalline precipitate with soluble phosphates and ammonia.

ALUMINUM.—Al 14.

(295.) Alumina, as the basis of pure clay, is abundantly distributed. Aluminum may be prepared as directed for magnesium. It is a grey powder, like platina in appearance, very difficult of fusion. It is not oxidized by exposure to air, but when heated nearly to redness, burns into alumina. It is acted on by boiling water, a little hydrogen being given off; in this case, however, the oxidizement is superficial.

(296.) OXIDE OF ALUMINUM. SESQUIOXIDE OF ALUMINUM. ALUMINA. $Al^2 O^3$.—It may be obtained by exposing dry ammonia alum to heat. It is a very white soft powder, difficultly acted on by acids, and very hard; its specific gravity, thus prepared, is about 4; if prepared by precipitation, it is about 2, and much more soluble; in this case, however, it is a hydrate. Alumina has a great affinity for colouring matter. If ammonia be added to a solution of alum in infusion of cochineal or madder, the colouring matter falls in combination with the alumina. Colours thus prepared, are called *lakes*.

Alumina is a feeble base, and it also combines with the stronger bases, as an acid would. It consists of—

	Atoms.	Weight.	per Cent.
Aluminum . .	2	28	53.8
Oxygen . . .	3	24	46.2
Alumina . . .	1	52	100.0

Native alumina constitutes the sapphire, the ruby, and the topaz. Corundum and emery are nearly pure alumina; all these minerals are excessively hard, inferior only to the diamond. There are several hydrates of alumina.

(297.) CHLORIDE OF ALUMINUM, Al^2Cl^3, may be formed by passing dry chlorine over an intimate mixture of alumina and charcoal; carbonic oxide is given off, and chloride of aluminum sublimes. It cannot be obtained from a solution of alumina in hydrochloric acid, as it retains the water so obstinately that it evolves hydrochloric acid, and alumina is left.

(298.) SULPHATE OF ALUMINA, Al^2O^3, $3\,SO^3$, is formed by digesting hydrate of alumina in dilute sulphuric acid; it dissolves in two parts of water, and forms crystals, which contain 18 equivalents of water.

(299.) SULPHATE OF ALUMINA AND POTASH. POTASH ALUM. $KO\,SO^3$, Al^2O^3, $3\,SO^3 + 24\,HO$.—This salt is manufactured on an extensive scale in this country, from a kind of slaty clay, abounding in bisulphuret of iron; this is gently roasted, moistened, and exposed to the air; oxygen is absorbed, sulphate of iron and sulphate of alumina are formed, which are separated by lixiviation in water. The solution is concentrated and mixed with chloride of potassium, by which means sulphate of potash is formed, and chloride of iron, which is exceedingly soluble, remains in solution, while the sulphate of potash and sulphate of alumina crystallize together as alum. Sometimes alum is manufactured by the direct action of sulphuric acid on clay, and the addition of sulphate of potash. Potash alum crystallizes in colourless transparent octohedra; specific gravity 1.72; it has a sweetish astringent taste, reddening litmus paper. It requires 18 parts of water at 60° for solution, and its own weight of boiling water. It is largely employed in the arts. If dried alum and sugar be mixed, and the sugar carbonized in an open pan by heat, the mixture put into a coated phial, and exposed to a red heat, the contents of the phial, when cold, will take fire on shaking out into the air. This was known as Homberg's Pyrophorus; the essential ingredient is finely divided sulphuret of potassium.

Soda Alum.—Sulphate of soda replaces sulphate of potash. Soda alum is more difficult to crystallize than potash alum.

Ammonia Alum.—Sulphate of ammonia may be used instead of sulphate of potash; it has very nearly the same degree of solubility as potash alum, and much resembles it. It is manufactured for commercial use, sulphate of ammonia being cheaper than sulphate of potash.

Alumina is very abundantly distributed in nature; the clays are alumina and silica. Granite, also, contains it. The composition assigned to Felspar, is—

$$Al^2\,O^3 + 3\,Si\,O^3 + K\,O\,Si\,O^3,$$

or a silicic acid instead of sulphuric acid alum. Garnet and mica are silicates of lime and alumina.

(300.) *General Characters of the Salts of Alumina.* — Caustic potash and soda throw down white gelatinous precipitates, which are re-dissolved on adding an excess of the precipitants.

The same with ammonia, but the precipitate is not re-dissolved with excess.

The alkaline carbonates precipitate hydrate of alumina, which is not soluble in an excess of precipitant.

GLUCINUM.—G 27.

(301.) This, and the next eight metals, are mere chemical curiosities, being prepared from a few rare minerals.

Glucina is found in the emerald, beryl, and euclase; it much resembles alumina. Its salts have a sweet taste; and the composition of glucina is G^2O^3.

Glucinum is prepared from the chloride of glucinum like aluminum.

YTTRIUM.—Y.

(302.) This is found in gadolonite and other rare minerals; it is named from Ytterby, in Sweden. The metal is prepared as aluminum.

(303.) **ERBIUM** and **TERBIUM** are found associated with yttrium.

(304.) **CERIUM**, **LANTHANUM**, and **DIDYMIUM**, are found in a rare Swedish mineral, cerite; they are separated with great difficulty. Didymia stains glass an amethyst colour.

ZIRCONIUM.—Z 23.

(305.) **ZIRCONIUM** is prepared by heating the double fluoride of zirconium and potassium with potassium, and dissolving away the fluoride of potassium in cold water. It is a black powder.

(306.) Zirconia resembles alumina; it is extracted from the mineral zircon, which also contains Norium.

THORIUM.—Th.

(307.) Thorium is contained in thorite, a rare mineral; it is like aluminum, and is obtained in the same way.

(308.) Thorina, $Th\,O$, is distinguished by great specific gravity.

MANGANESE.—Mn 28.

(309.) Manganese occurs abundantly in the form of the peroxide. It may be obtained by exposing carbonate of manganese mixed with charcoal to an intense heat, in a covered crucible. It is a greyish white metal, resembling cast-iron, very difficult of fusion; specific gravity 8; oxidizing so rapidly in air, that it requires to be kept under naphtha. It does not decompose water in the cold.

Oxides of Manganese. There are seven, viz.:—

Protoxide	$Mn\,O$
Sesquioxide	$Mn^2\,O^3$
Peroxide	$Mn\,O^2$
Red Oxide	$Mn^3\,O^4$
Varvicite	$Mn^4\,O^7$
Manganic Acid	$Mn\,O^3$
Hypermanganic Acid . .	$Mn^2\,O^7$

(310.) Protoxide of Manganese. $Mn\,O$.—When carbonate of manganese is heated in a stream of hydrogen, carbonic acid is expelled, and a green anhydrous protoxide, which rapidly absorbs oxygen, remains. It is a powerful base; it dissolves in acids, forming neutral salts. When alkalies are added to solutions of the protoxide, a nearly white hydrate falls, which becomes brown by the absorption of oxygen.

(311.) SESQUIOXIDE, Mn^2, O^3, occurs native. It may be prepared by exposing the native peroxide to a moderate heat. It is the principal part of the residue found in the retort after the preparation of oxygen from the peroxide; it is a feeble base, isomorphous with the sesquioxide of iron and with alumina. Sulphate of the sesquioxide forms an alum with sulphate of potash, which is, however, decomposed by water. Heated with hydrochloric acid, protochloride is formed, and chlorine evolved. Hot sulphuric acid destroys it, oxygen being given off. Nitric acid converts it into protoxide and peroxide, combining with the former.

(312.) PEROXIDE OF MANGANESE, MnO^2, is found native in masses or crystallized. Its appearance in commerce is usually that of a fine black powder. It is decomposed by hydrochloric acid with the evolution of chlorine, and chloride of manganese is formed. Heated with boiling oil of vitriol, oxygen is given out, and sulphate of the protoxide formed. It is principally used for the preparation of chlorine on the large scale. It is very often adulterated with powdered charcoal, in which case it gives out carbonic acid when heated; a hydrated peroxide exists.

(313.) RED OXIDE OF MANGANESE, $Mn^3 O^4$, occurs native. Some chemists regard it as a compound of protoxide and sesquioxide.

(314.) VARVICITE is found native at Hartshill, in Warwickshire. It consists of one equivalent of sesquioxide and one of peroxide.

(315.) MANGANIC ACID. MnO^3.—When peroxide of manganese is heated to full redness with nitre, or, still better, with caustic potash in excess, a green substance is obtained, which is manganate of potash. If the alkali be in excess, it is permanent, and forms a green solution; if not, it becomes blue, purple, and ultimately red, and deposits hydrated peroxide. From this circumstance it has been called "mineral chamelion." Manganic acid has not been insulated; on attempting to do so with a stronger acid it is resolved into oxygen and hydrated peroxide.

(316.) PERMANGANIC ACID. HYPERMANGANIC ACID. Mn^2O^7.—This may be isolated as follows:—Prepare a manganate of baryta by heating peroxide of manganese with nitrate of baryta. To this add a little sulphuric acid, which will convert it into permanganate, forming a red solution; evaporate carefully, and decompose with sulphuric acid; solution of permanganic acid is the result. Evaporate carefully, and pour off the acid from the deposited sulphate; it crystallizes in carmine-red needles. Its aqueous solution is a splendid carmine red. The contact of combustible substances decomposes it. Thus it cannot be filtered, as the paper absorbs its oxygen, and hydrated peroxide is deposited. Its salts are mostly of a red or purple hue, and deflagrate with combustibles.

(317.) PROTOCHLORIDE OF MANGANESE, $Mn\,Cl$, may be obtained by filtering the residue from the preparation of chlorine, evaporating to dryness, and then slowly heating to dull redness, by which the chloride of iron, the principal impurity, is either volatilized or converted into the oxide. The resulting greyish mass is to be heated with water, and evaporated to dryness; any trace of iron may be got rid of by carbonate of manganese.

Fused chloride of manganese much resembles chloride of magnesium. 100 parts of water dissolve 38 parts at 50°, and 55 parts at 144°, when it becomes less soluble. It crystallizes in rose-coloured tabular crystals, containing 4 equivalents of water, and deliquescent.

The PERCHLORIDE, $Mn^2 Cl^7$, is a green vapour, condensible at 6° into a volatile liquid.

(318.) SULPHATE OF MANGANESE, $MnO, SO^3 + 7 HO$, is a rose-coloured very soluble salt. It may be prepared by dissolving protoxide or carbonate in sulphuric acid. It is largely prepared by dissolving an impure protoxide, made by igniting the peroxide of commerce with charcoal or coal-dust. The iron is got rid of by heating red-hot and again dissolving, as directed for the chloride. It is used by the dyers. The cloth is impregnated with a solution of sulphate of manganese, and then put into bleaching liquid; hydrated peroxide falls, which, being imprisoned in the cloth, cannot be washed out. The colour is called manganese brown. It is soluble in two parts of water at 60°, and its own weight at 122°, after which its solubility diminishes.

(319.) CARBONATE OF MANGANESE, $Mn O, C O^2$, is found native, and is known as spathose manganese. It may be prepared artificially by precipitating a salt of manganese with an alkaline carbonate, when it falls as a buff-coloured hydrate.

General Character of the Salts of Manganese.—The behaviour of the salts of this metal, with tests, is fully given in the Table.

IRON.—Fe 28.

(320.) This most important and useful metal is very extensively distributed; it is found as an oxide, carbonate, sulphuret, and in very small quantities native. It is also to be discovered in animals and vegetables, and in some mineral waters.

Iron is a grey metal, fusible at a full white heat, but with very great difficulty when quite pure. In bars it is fibrous, but when kept a long time at a red heat becomes crystalline. Its specific gravity is 7.77 to 7.8; it is the hardest and toughest of the ductile metals; it may be drawn into very fine wire, which is very strong. It admits of being welded; that is, if two pieces of iron, at a full red or white heat, be placed in contact and hammered, they unite, and the junction is as strong as any other part. The only other metals that weld are platinum and sodium. It is attracted by the magnet, but does not itself retain magnetism when quite pure and soft. It conducts electricity badly; nevertheless it is used for the wires of the electric telegraph, for though a copper wire would conduct better, iron is so much cheaper, that the difference may be economically made up by a greater thickness, thick wires conducting better than thin ones. Large lumps of very nearly pure iron are found in detached masses. These are of meteoric origin. A large lump was seen to fall from the air in Croatia, as a mass of fire; it is now preserved in the Imperial Museum at Vienna.

Exposed to air, iron rusts or oxidizes; it does so with greater rapidity when in water, especially if the water be open to the air. Acids and neutral salts cause it to rust; alkalies preserve it. Hence bright iron goods may be preserved by powdering them, or keeping them in a box with quicklime. A stove may be preserved by greasing or oiling, and then dusting over with quick-lime. This, however, is not so efficacious as where pure quick-lime can be applied, probably from the oil becoming acid. The affinity of iron for oxygen is very great; so much so, that when in a minute state of division, it requires the same precautions to preserve it as potassium. By contact of zinc iron is preserved from all ordinary sources of corrosion. A patent has been taken out for covering iron plate and wire with a coating of zinc; this is known as galvanized iron.

OXIDES OF IRON.—There are four; namely,

Protoxide	FeO
Sesquioxide	Fe^2O^3
Black Oxide	Fe^3O^4
Ferric Acid	FeO^3

(321.) PROTOXIDE OF IRON. Fe O.—When solution of potash is added to a pure solution of a protosalt of iron, a white precipitate falls, which, except air be very carefully excluded, absorbs oxygen. This is the hydrated protoxide. If dried under entire exclusion of air, it is pale greenish friable powder, which exposed to air becomes hot, and is converted into the peroxide. It consists of—

	Atoms.	Weight.	per Cent.
Iron	1	28	77.77
Oxygen	1	8	22.23
Protoxide of Iron . . .	1	36	100.00

It is a very powerful base, neutralizing acids most completely.

(322.) SESQUIOXIDE OF IRON. PEROXIDE OF IRON. Fe^2O^3.—When a protosalt of iron is boiled with nitric acid, it becomes peroxidized; and on adding ammonia a brown hydrated precipitate falls, which, when washed and ignited, is sesquioxide. It is prepared also by decomposing the protosulphate at a high temperature; a red powder remains, called *colcothar*. It is used as a polish for metals. It consists of—

	Atoms.	Weight.	per Cent.
Iron	2	56	70
Oxygen	3	24	30
Sesquioxide of Iron . .	1	80	100

It is a weak base, isomorphous with alumina.

(323.) Black Oxide. Magnetic Oxide. Fe^3O^4.—It occurs native as the octohedral magnetic iron ore, or loadstone. It may be prepared by mixing due proportions of a proto and per-salt of iron, and precipitating, and then boiling the mixed hydrates, they unite into minute crystals of magnetic oxide. This is also the chief product of the oxidation of iron at a high temperature. It is not salifiable. It is magnetic, which the two former are not.

(324.) Ferric Acid. $Fe\,O^3$.—Pure and finely divided oxide of iron is mixed with four parts of dried nitre, and exposed for about an hour to a full red heat in a covered crucible, a dark brown deliquescent mass is the result, which is ferrate of potash. Its solution must be made in ice-cold water, as it is rapidly decomposed by heat. It gradually evolves oxygen, and deposits peroxide even in the cold.

Salts of baryta throw down a bulky red precipitate of ferrate of baryta, which is insoluble, and permanent.

(325.) Protochloride of Iron, $FeCl$, is formed by passing dry hydrochloric acid gas over iron heated red-hot, or by dissolving iron filings in hydrochloric acid. The solution yields green crystals, which contain 4 equivalents of water, and are deliquescent; heated with access of air sesquichloride of iron sublimes, and peroxide remains.

(326.) PERCHLORIDE OF IRON. SESQUICHLORIDE OF IRON. Fe^2Cl^3.—Equal weights of chloride of calcium and calcined sulphate of iron are heated together. Sesquichloride of iron sublimes in iridescent brown crystals. It is very deliquescent; and if its solution be evaporated to dryness and strongly heated, most of it is decomposed into peroxide and hydrochloric acid. It dissolves freshly precipitated peroxide.

(327.) PROTIODIDE OF IRON, FeI, is a most valuable medicine; it is prepared by digesting iodine and iron filings together in water, taking care to have excess of the latter. It should be evaporated out of contact with air; and as it is liable to peroxidize, some clean pieces of iron wire should be kept in it.

(328.) PROTOSULPHURET OF IRON, FeS, is a blackish brittle substance, attracted by the magnet, formed by heating together iron and sulphur; it is dissolved by dilute acids with the evolution of sulphuretted hydrogen.

(329.) BISULPHURET OF IRON, FeS^2, is found native; the common yellow pyrites being a bisulphuret of iron. Nodules of this substance, of a brass colour, and very hard, are found on the coast of Kent and Sussex; they are called by the country people thunder-bolts. They emit sulphur when heated, and are used in manufacturing sulphuric acid and sulphur.

(330.) SESQUISULPHURET OF IRON, Fe^2S^3, is formed when persulphate of iron is added to a solution of an alkaline hydrosulphuret. It is a dark brown powder.

(331.) Protosulphate of Iron, $FeO\ SO^3$, is the copperas and green vitriol of commerce. It may be prepared by dissolving iron filings in sulphuric acid. It is manufactured on the large scale by exposing iron pyrites to the combined influence of air and moisture: it forms bluish-green oblique rhombic prisms, specific gravity 1.8, containing 7 equivalents of water; these slowly effloresce, and peroxidize in the air. It is soluble in about twice its weight of cold water, and the solution is of a green colour, and inky taste. It forms double salts with sulphate of potash, and ammonia.

(332.) Persulphate of Iron, $Fe^2O^3, 3SO^3$, is prepared by adding to the above one-half as much sulphuric acid as it already contains, and peroxidizing by the addition of nitric acid to the boiling mixture; the red liquor must be evaporated to dryness, and heated so as to expel the nitric acid. It forms double salts with sulphate of potash, soda, and ammonia, resembling the alums.

(333.) Protonitrate of Iron. FeO, NO^5.—When dilute cold nitric acid acts on iron, and the solution is evaporated in vacuo, pale green crystals are formed of the protonitrate, and very soluble.

(334.) Pernitrate of Iron is readily formed by pouring nitric acid on iron; it is much used in dyeing. It often deposits an insoluble subnitrate.

(335.) Protocarbonate of Iron, $FeO\ CO^2$, is thrown down when a protosalt of iron is mixed with an alkaline carbonate. It cannot be washed without losing carbonic acid, and absorbing oxygen. It occurs native in the English clay ironstone. It is often found in mineral waters, it being soluble in excess of carbonic acid. When such waters are exposed to air carbonic acid escapes, and a rusty powder is deposited. Percarbonate of iron is unknown.

(336.) **Iron** and **Cyanogen** form several important compounds.

Ferrocyanogen. $Fe\,Cy^3$.—It is doubtful if this radicle has ever been isolated: it exists, however, in an important class of salts, called ferrocyanides, or formerly prussiates.

Hydroferrocyanic Acid. Cfy^2H.—Ferrocyanogen unites with hydrogen. Ferrocyanide of lead is suspended in water and sulphuretted hydrogen passed through it, the solution filtered, and evaporated under the air-pump; a white residue remains. It is soluble in water; the solution is sour, and decomposes the alkaline carbonates with effervescence: it exhibits no properties in common with the cyanides, and is not poisonous; it is permanent in the dry state, but when moistened and long exposed to air passes into Prussian blue.

Ferrocyanogen is usually denoted by the symbol Cfy.

(337.) **Ferrocyanide of Potassium.** K^2Cfy, or $Fe\,K^2\,3\,Cy$.—This salt is usually called prussiate of potash. It is manufactured on a large scale. Into an iron pot is projected a mixture of good pearlashes and dry animal matters, 2 of pearlash to 5 of dry horns or hoofs; iron filings should also be supplied; this is brought to moderate ignition, and is dexterously stirred with an iron ladle; the mass is then allowed to cool and lixiviated, and the evaporated solution yields a crop of impure crystals; these are dissolved in water and slowly crystallized, when large and very regular crystals are obtained. The theory of this process is, that the potash of the pearlashes is decomposed by the charcoal, and the reduced potassium unites with another portion of the carbon and nitrogen of the animal matters. Thus a cyanide of potash is formed, which afterwards unites with the iron, forming ferrocyanide of potassium.

Ferrocyanide of potassium forms lemon-yellow crystals, specific gravity 1.83; water at 60° takes up a third, and at 212° its own weight. The crystalline form is a four-sided table, derived from the octohedron, and contains three equivalents of water.

(338.) The ferrocyanides are often described as double salts, in which protocyanide of iron is combined with other metallic cyanides or hydrogen; thus: hydroferrocyanic acid is $Fe\,Cy + 2\,H\,Cy$, and ferrocyanide of potassium $Fe\,Cy + 2\,K\,Cy + 3\,H\,O$. This view has the merit of simplicity, but is not supported by experiment; it is better to consider ferrocyanogen as a bibasic radicle.

(339.) When ferrocyanide of potassium is added to a persalt of iron, a blue precipitate falls, whose composition, though it was discovered so early as 1710, is not yet satisfactorily determined; it consists, when anhydrous, of 7 equivalents of iron and 9 of cyanogen, though it is to be doubted whether water is not essential. This substance is known in commerce as PRUSSIAN BLUE, and is extensively used as a dye stuff and colour; it is an exceedingly beautiful blue, which, when in mass, has a coppery tinge. It is tasteless and inodorous, and is not poisonous. It is best prepared by adding ferrocyanide of potassium to the pernitrate of iron. It is not soluble in water or acids, except oxalic. Heated in air it burns like tinder, and a residue of peroxide of iron is left. Concentrated oil of vitriol converts it into a white pasty mass, which again becomes blue on the addition of water. Exposed to heat it is decomposed into water, cyanide of ammonium, carbonate of ammonia, and leaves a residue of carburet of iron.

(340.) BASIC PRUSSIAN BLUE. $3 Cfy\, 4 Fe + Fe_2 O^3$.—This is a combination of Prussian blue with peroxide of iron. It is formed when the white precipitate from a protosalt of iron is exposed to air. It is soluble in water, but not in saline solutions.

(341.) FERROCYANIDE OF IRON.—A white precipitate falls when a protosalt of iron is added to ferrocyanide of potassium; it seems, however, not to be a pure proto-ferrocyanide of iron, as it always contains potassium.

The other ferrocyanides are of no great importance.

(342.) FERRIDCYANOGEN. $Fe^2 Cy^6$, or Cfdy.—This is the name given to a presumed radicle, which is tribasic and isomeric with ferrocyanogen. Its symbol is Cfdy.

(343.) FERRIDCYANIDE OF HYDROGEN.—HYDROFERRIDCYANIC ACID, $Cfdy\, H^3$, is prepared as directed for hydroferrocyanic acid from the ferridcyanide of lead. By filtration a yellow liquid is obtained, which by spontaneous evaporation deposits crystals; if heat be used, a brown powder remains.

(344.) FERRIDCYANIDE OF POTASSIUM.—Chlorine is passed through a solution of ferrocyanide of potassium till the liquor ceases to precipitate Prussian blue from the persalts of iron; if it be then filtered, it deposits on slow evaporation rhombic prismatic crystals, of a ruby-red colour, sometimes improperly called red prussiate of potash. They are anhydrous, and require nearly 4 parts of water for solution. It occasions a beautiful blue precipitate in salts of the protoxide of iron, but none with those of the peroxide. It consists of 3 equivalents of potassium and 1 of ferridcyanogen, or $3K, Cfdy$.

(345.) FERRIDCYANIDE OF IRON. $Fe^{3}Cfdy$.—This is the precipitate formed by adding solution of ferridcyanide of potassium to solution of a protosalt of iron. It is known in commerce as TURNBULL'S BLUE. It is brighter than ordinary Prussian blue.

Ferrocyanide of potassium and ferridcyanide are both valuable tests, causing characteristic precipitates in most metallic salts.

METAL.	FERROCYANIDE.	FERRIDCYANIDE.
Manganese	White	Brownish grey.
Iron, protosalts	White, turning blue	Deep blue.
„ persalts	Deep blue	None.
Zinc	Yellowish white	Orange.
Tin, protosalts	White, then yellow	White.
„ persalts	Pale yellow.	
Cadmium	White.	
Copper, protosalts	Lilac	Dirty yellow brown.
„ persalts	Deep brown.	
Lead	White.	
Antimony	Ditto.	
Bismuth	None.	
Cobalt	Pale green	Dark red-brown.
Uranium	Deep brown	Reddish brown.
Nickel	Grey	Yellowish Brown.
Mercury	Greenish white	Yellow.
Palladium	Olive.	
Silver	Cream colour	Orange yellow.
Gold	None.	
Platinum	Yellow.	

For the details of the manufacture of iron, the student is referred to the little work on that subject published by the Society for Promoting Christian Knowledge.

Steel and cast-iron are CARBURETS of iron.

NICKEL.—Ni 28.

(346.) Nickel is found in the Hartz Mountains, chiefly as an arsenuret. It was called by the Germans, "kupfer nickel," or false copper, "nickel" being a term of detraction. Its common commercial ore is called speiss, and is an impure arsenuret. Nickel may be obtained by exposing the oxalate to an intense white heat, in a crucible lined with charcoal. It is a white malleable metal, very infusible. Specific gravity, 8.5. It is magnetic, but loses this property when heated to 630°.

Nickel unites with oxygen in two proportions.

(347.) PROTOXIDE OF NICKEL, NiO, is prepared by heating the nitrate to redness, or precipitating a salt of nickel with caustic potash, and igniting the resulting apple-green hydrate. It is an ash-grey powder, freely soluble in acids, which it neutralizes. The salts of this base are usually of a beautiful green colour.

(348.) PEROXIDE OF NICKEL, Ni^2O^3, is produced when a salt of nickel is mixed with a solution of bleaching powder. It is a black insoluble substance, not salifiable.

(349.) CHLORIDE OF NICKEL, $NiCl$, is prepared by dissolving oxide of nickel in hydrochloric acid. It furnishes green crystals containing water; when rendered anhydrous it is yellow, unless it contain cobalt, when it remains green.

(350.) SULPHATE OF NICKEL, $NiO, SO^3 + 7HO$, may be formed by dissolving the oxide in sulphuric acid. It forms green prismatic crystals, soluble in

3 parts of cold water. When a strong solution of oxalic acid is mixed with sulphate of nickel, a bluish green precipitate falls, which is the oxalate.

(351.) CARBONATE OF NICKEL, NiO, CO^2, is the pale-green precipitate which falls on adding carbonated alkali to a salt of nickel.

(352.) The salts of nickel may be prepared from speiss, as follows:—The mineral is broken into small fragments, mixed with one-fourth to one-half its weight of iron filings, and the whole dissolved in aqua regia. The solution is then evaporated to dryness, heated with boiling water, and the insoluble arseniate of iron filtered out. The liquid is then acidulated with hydrochloric acid, and heated with sulphuretted hydrogen in excess; and, after filtration, boiled with nitric acid, to peroxidize the iron. To the cold and largely diluted solution bicarbonate of soda is added, by which peroxide of iron is precipitated without loss of nickel. The solution is filtered and heated with carbonate of soda in excess. when the green carbonate of nickel falls, which may then be used as a source of all the other salts.

The most important alloy of nickel is German silver, as it is called, consisting of 100 parts copper, 60 zinc, and 40 nickel. There is now a large demand sprung up for this metal, in consequence of its forming the hard white alloy on which silver is deposited in making electro-plate.

COBALT.—Co 30.

(353.) This metal is seldom insulated, except by the chemist, for experiment, though its oxide is important in a commercial point of view in the preparation of the beautiful blue pigment called smalt. It may be prepared as nickel, which metal in many respects it much resembles. It is a white, brittle, and very infusible metal. Specific gravity, 8.5. It is magnetic; does not tarnish by exposure to air, and is feebly acted on by dilute acids.

There are two oxides.

(354.) **Protoxide of Cobalt**, CoO, is formed by adding potash to the nitrate, when it falls as a white hydrate, which afterwards becomes red from a change in the quantity of water. It may be obtained by heating the carbonate out of contact of air, when it is anhydrous and in the state of a grey powder. It communicates a most beautiful blue tint to glass.

Peroxide of Cobalt. Sesquioxide of Cobalt, Co^2, O^3, is prepared by adding solution of bleaching powder to chloride of cobalt. It is a black insoluble powder.

(355.) **Chloride of Cobalt**, $Co\,Cl$, is formed by dissolving the oxide in hydrochloric acid; it gives a deep rose coloured solution, which deposits hydrated crystals of the same colour. When the liquid is in very small bulk, it deposits anhydrous blue crystals; which by contact with water dissolve to a red liquid. If a drawing be made, the sky of which is tinted with a dilute solution of chloride of cobalt, in the cold it will be invisible; on putting it to the fire it will become of a blue colour, which will soon disappear again when it is taken away. The reason of this is that the heat of the fire drives off the water of hydration of the salt, forming the blue anhydrous salt; water is again absorbed from the atmosphere at the ordinary temperature.

(356.) **Sulphate of Cobalt.** $Co\,O, SO^3 + 7\,HO$. —This salt forms deep-red crystals, requiring for solution 24 parts of cold water. It forms double salts with sulphate of potash. Its form is identical with that of sulphate of magnesia.

(357.) NITRATE OF COBALT. CoO, NO^5.—With nitric acid, oxide of cobalt furnishes a brownish-red deliquescent salt, in irregular rhombic crystals. It forms a red sympathetic ink.

(358.) CARBONATE OF COBALT.—The alkaline carbonates throw down from solutions of cobalt a pale peach-blossom precipitate, which is a combination of the carbonate and hydrate. Oxalic acid precipitates nearly the whole of the cobalt as an insoluble oxalate.

(359.) PHOSPHATE OF COBALT may be formed by adding phosphate of soda to chloride of cobalt. It is insoluble in water, soluble in excess of phosphoric acid, and of a lilac colour.

Thenard's Blue.—When phosphate of cobalt is mixed with pure and moist alumina, and exposed to heat, it produces a beautiful blue colour, which is sometimes used as a substitute for ultramarine.

(360.) Oxide of cobalt is remarkable for the beautiful blue colour which it communicates to glass. The substance called smalt is made by roasting cobalt ore till it is nearly free from arsenic, and then fusing it with a mixture of potash and sand free from iron. A blue glass is formed, which is poured while hot into water, and ground to an impalpable powder. Zaffre is roasted cobalt ore mixed with sand, and reduced to powder; it is used in enamel painting.

ZINC.—Zn 32.

(361.) Zinc, or spelter, is a metal, the sulphuret and oxide of which are abundant. The carbonate occurs native, is known as calamine, and is a very valuable ore. The process for the reduction of zinc ores is simple; they are first roasted at a full red heat, by which sulphur, carbonic acid, &c. are expelled, and the zinc converted into an impure oxide. This is then heated with charcoal or coal, and the zinc distils and is condensed; it is then recast, and made into ingots.

Zinc is a bluish-white metal, hard and crystalline; density varying between 6.8 and 7.2; it is brittle. When exposed to a heat of between 250° and 300° it is malleable, and may be rolled and hammered; in this way the zinc of commerce is produced. At 400° it is very brittle, and may be reduced to powder; at 773° it melts; and boils at a full red heat. Dilute acids dissolve it readily with the evolution of hydrogen.

(362.) OXIDE OF ZINC. ZnO.—Only one oxide is known; it is a strong base. It may be prepared by burning zinc in the air; white flakes rise, which are oxide of zinc. It is a white tasteless powder; insoluble in water, but soluble in, and neutralizing acids. It becomes yellow by heat.

(363.) CHLORIDE OF ZINC, $Zn\,Cl$, may be formed by distilling together sulphate of zinc and chloride of sodium; or, in solution, by dissolving zinc filings in dilute hydrochloric acid. It is a white semitransparent substance; volatile at a bright red heat; very deliquescent. Sir William Burnett's preservative against dry rot is a dilute solution of the chloride.

(364.) SULPHATE OF ZINC. WHITE VITRIOL. $ZnO, SO^3 + 7\,HO$.—This salt is in appearance like Epsom salt. It is prepared by dissolving the metal in dilute sulphuric acid; or by roasting the sulphuret. It has an astringent metallic taste, and is used in medicine as an emetic. It is soluble in two parts of cold, and much less of hot water.

(365.) Carbonate of Zinc, ZnO, CO^2, is precipitated when solution of zinc is mixed with an alkaline carbonate; it is then mixed with hydrate. It is found native.

(366.) The use of zinc is well known: it is employed in roofing, and in gutters and chimney-pots. It speedily becomes covered with a white oxide, which protects the metal.

CADMIUM.—Cd 56.

(367.) This metal was discovered in 1817, by Stromeyer. It usually accompanies zinc; it resembles tin in colour, but is harder; it is very malleable; density, 8.7; melts below 500°, and is nearly as volatile as mercury. It tarnishes but little in the air, but burns when strongly heated. It is best dissolved by nitric acid.

(368.) Salts of Cadmium.—

Salt.	Symbol.	Preparation.	Properties.
Sulphate....	$CdO\,SO^3$	Dissolving oxide in sulphuric acid	Very soluble, forming double salts with potash and soda.
Chloride....	$Cd\,Cl$	Dissolving oxide in hydrochloric acid.........	Very soluble, crystallizing in 4-sided prisms.
Sulphuret..	$Cd\,S$	Precipitating soluble salts with sulphuretted hydrogen	Bright yellow, fusible compound, very characteristic.

The oxide is prepared by igniting the carbonate; it is pale brown, infusible, and soluble in acids. The sulphuret has been used as a paint.

BISMUTH.—Bi 213.

(369.) This is a metal not very abundant: it *occurs* native. It is a brittle white metal, with a slight shade of red; its specific gravity is 9.8; it fuses at 476°, and is volatile at a high red heat. It crystallizes on cooling: to show this, a large quantity—one or two pounds—should be put into a crucible, and melted; then, when the inner part still remains fluid, the solid crust should be pierced, and the inner part poured out: the metal will be found crystallized in cubes.

(370.) There are three oxides of bismuth.

The SUBOXIDE is said to be formed when bismuth is heated above the melting point.

(371.) OXIDE OF BISMUTH. PROTOXIDE OF BISMUTH. $Bi O^3$.—The best method of preparing this is to dissolve bismuth in nitric acid, precipitate by the addition of water, and heat nearly to redness. It is yellow, fusing into a brown liquid, and forms a white hydrate with water.

(372.) PEROXIDE OF BISMUTH, BISMUTHIC ACID, $Bi O^5$, is formed when bismuth is fused with potash. Its acid properties are by no means decided.

(373.) NITRATE OF BISMUTH. $Bi O^3, 3 N O^5 + 9 H O$.—When bismuth is dissolved in moderately strong nitric acid, and the whole left to cool, large colourless transparent crystals of the neutral salt are formed. Water decomposes this salt, an acid solution is obtained, and a brilliant white crystalline powder falls, which is subnitrate—

$$Bi O^3, N O^5, H O.$$

The water, therefore, acts as a base, taking nitric acid from oxide of bismuth. This is not an uncommon occurrence.

SUBNITRATE OF BISMUTH, or magistery of bismuth, was employed at one time for painting the skin, but is said to injure it, making it yellow and leathery.

(374.) Bismuth is used in soft solders: 5 parts lead, 3 of tin, and 8 of bismuth, form the fusible metal melting at 212°. It is employed in taking impressions from dies. Casts may be taken from plaster in this metal, and the mould thus formed may be used for taking impressions by the electrotype process.

URANIUM.—U 60.

(375.) This metal exists in pitchblende and uranite. It is prepared by the decomposition of the chloride by potassium: it is obtained in the form of a black powder.

(376.) Protoxide of Uranium. U O.—This was at one time supposed to be the metal. It is a brown powder. It forms green salts with acids.

(377.) Deutoxide of Uranium, Black Oxide, $U^4 O^5$, is produced when the protoxide, or the peroxide, are strongly heated in air. It is a black powder, which does not form salts.

(378.) Peroxide of Uranium, U^2O^3, is salifiable, forming beautiful yellow salts. When caustic alkali is added to pernitrate of uranium, a yellow hydrate falls. The anhydrous oxide is of a pale yellow colour.

Uranium is used in staining glass. The protoxide gives a black, and the peroxide a delicate yellow colour.

COPPER.—Cu 32.

(379.) This useful metal has been known from very early ages; its most plentiful ore is the sulphuret of iron and sulphuret of copper, or yellow copper ore. Large quantities of this ore are yearly shipped to Swansea, in order to be smelted.

It is not smelted in Cornwall, where it is raised, as the weight of ore is less than that of the coal required to smelt it. The process of reduction is complicated; it consists in roasting, by which the iron is converted into oxide, and arsenic and sulphur expelled, the sulphuret of copper remaining unaltered. This is then fused with sand, which combines with the iron as a glassy slag, while the sulphuret of copper remains. The iron is got rid of by a repetition of these processes, and then the sulphuret of copper is reduced, by heat and air, to the state of oxide: this is then heated with charcoal. The last part of the operation is poling—thrusting a pole of beech into the melted metal; it reduces the oxide of copper mixed with the metal.

Copper is of a reddish colour; specific gravity 8.96; very malleable and ductile; fusible at a low white heat, and volatile at a very high temperature. Exposed to moist air, it becomes coated with a green crust of carbonate; heated to redness, a black scale of oxide peels off. Nitric acid, even dilute, readily dissolves it; sulphuric and hydrochloric acid act on it but slowly in the cold.

(380.) **Suboxide of Copper**, Cu^2O, may be obtained by heating 5 parts of protoxide with 4 of copper filings. It forms colourless salts with acids which show a great tendency to absorb oxygen, and are unstable.

(381.) **Protoxide of Copper**, CuO, may be prepared by heating copper in air, when the scales that peel off are protoxide; or by decomposing the nitrate by heat. It is the base of the ordinary salts of copper. When a salt of copper is mixed with caustic alkali, a blue precipitate falls, which at 212° becomes black, being converted into the anhydrous oxide. The hydrate is decomposed even in the presence of water at a high temperature.

(382.) CHLORIDE OF COPPER, $CuCl$, may be formed by dissolving protoxide in hydrochloric acid, and evaporating at a temperature below 400°. It is very soluble, giving a green solution; at a gentle heat, it parts with water of crystallization, and becomes yellow. By heat it is resolved into a white fusible substance, chlorine being evolved: this is subchloride.

(383.) SULPHATE OF COPPER, Blue Vitriol, $CuO, SO^3 + 5HO$, is prepared by oxidating the sulphuret; it is also a large product of the gold and silver refiners. It forms rhomboidal crystals of a blue colour; soluble in 4 parts of cold, and 2 of boiling water. It is now largely used in the electrotype process. With ammonia it forms a double salt of a beautiful blue colour.

(384.) CARBONATE OF COPPER occurs native as malachite, a beautiful green mineral. It consists of—

$$2CuO, CO^2, HO.$$

Verditer is a blue pigment, made by mixing chalk with nitrate of copper. It requires certain precautions in its preparation, in order that a fine blue may be produced.

The alloys of copper are important: copper and zinc form brass; about 70 parts copper to 30 zinc. It is cheaper than copper, and in many respects preferable, as it is little liable to rust.

Speculum metal is a mixture of copper and tin. The great mirror of Lord Rosse's telescope consists of copper 126, tin 59. It is white, hard, and bears a very brilliant polish.

The use of copper in coinage is well known: 24 pence weigh a pound avoirdupois. By the law of England, no person need receive more than 12*d*. of a debt in copper, or 40*s*. in silver; the rest must be paid in gold or notes.

(385.) *Poisoning with Copper.*—The salts of copper are sometimes used with a criminal intent. The tests in the Table will give almost unmistakeable indications; the best method, especially in thick fluids, is precipitation, as follows:—Render acid the suspected liquid, with a drop or two of dilute sulphuric acid, and then suspend a clean sewing needle in it: in a day or two it will become covered with a coating of copper. Or put a drop or two of the suspected liquid upon a piece of clean platinum foil; touch it with a piece of zinc; a pink film of copper will be deposited on the platinum.

LEAD.—Pb 104.

(386.) Lead has been known from the earliest ages. Its principal ore is the native sulphuret, or galena. This is reduced by roasting in the usual way. Lead is a bluish-white metal, very soft; it leaves a black streak when drawn over paper. It can be rolled into thin leaves. It melts at 612°, and is readily oxidized when exposed to heat and air. Its specific gravity is 11.4; it contracts considerably in cooling, so that the casts made with it are not good. It undergoes little change in the air at common temperatures, hence its extensive use for eaves and gutters. Pure water corrodes it, but not that which contains, as most spring waters do, carbonates and sulphates. Several valuable pigments are produced from combinations of lead.

There appear to be five oxides of lead:—Suboxide, protoxide, red oxide, sesquioxide, and peroxide.

(387.) DINOXIDE, Pb^2O, is formed by heating oxalate of lead to dull redness in a retort. It is a grey pulverulent substance; it absorbs oxygen when heated, or even when moistened and exposed to air.

(388.) PROTOXIDE OF LEAD, PbO, is prepared by oxidating the metal by heat and air. Litharge is an impure protoxide, which has been fused. Protoxide of lead is a straw yellow, very heavy, slightly soluble in water, giving an alkaline liquid; at a red heat, it melts. It unites with silica. English flint glass contains much lead. It forms a number of salts, with acids, most of which are colourless.

(389.) RED OXIDE OF LEAD, RED LEAD, Pb^3O^4, is made by exposing protoxide to a low red heat. It is a brilliant red and heavy powder, much used as a common paint. It requires certain precautions for its successful manufacture, and is not very definite in composition. Acids convert it into protoxide and peroxide.

(390.) SESQUIOXIDE OF LEAD, $Pb^2 O^3$, is an orange-yellow powder, formed by adding solution of chloride of soda to a salt of lead. It behaves with acids as the above.

(391.) PEROXIDE OF LEAD. PLUMBIC ACID. $Pb O^2$.—This may be procured by digesting red lead in nitric acid; protoxide is dissolved, and the peroxide remains as a brown powder. It is decomposed by heat, yielding up half its oxygen, and passing into protoxide; with hydrochloric acid chlorine is evolved; sulphuric acid liberates oxygen, and forms sulphate of lead. It absorbs sulphurous acid, sulphate of lead being produced; hence it is used to separate sulphurous acid from gaseous mixtures. With solution of ammonia it becomes converted into nitrate of lead and water.

(392.) **Chloride of Lead.** $PbCl$.—When strong solution of acetate of lead and chloride of sodium are mixed, chloride of lead falls as a white powder. It requires about 135 parts of cold water for solution, and crystallizes in needles; it is anhydrous, and melts when heated, becoming horny on cooling.

(393.) **Iodide of Lead.** PbI.—Iodide of lead separates when iodide of potassium is added to a soluble salt of lead; it is a brilliant yellow colour. It dissolves in hot water, forming a colourless solution, which deposits the iodide on cooling in golden scales.

(394.) **Carbonate of Lead. White Lead.** PbO, CO^2.—This is a white, heavy, insoluble powder. It may be prepared by precipitating a soluble salt of lead by an alkaline carbonate; it is not fit, however, for a pigment when prepared in this way. The method of its manufacture for painters is as follows:—A large number of earthen jars are prepared, into which are poured a few ounces of vinegar; a roll of lead is then put into the jar, so as not to touch the vinegar, nor project above the top of the jar. These are arranged side by side in a bed of spent tan, covered with boards; spent tan is placed on these, with another set of jars, and so on; in this manner a stack, consisting of layers of jars in tan and boards, is built up; it is left some weeks; the pile is then taken down, and the lead is found converted to a considerable depth into carbonate. This is scraped off from the core of lead which remains, ground and washed, till fit for use. The theory is that the acetic acid first converts the lead into a subacetate, which is again decomposed by the carbonic acid arising from the fermenting bark, the heat produced serving to keep the acetic acid in a state of vapour. White lead thus prepared is of a better quality than that prepared by precipitation; it has more *body;* less of it, that is, covering the wood to be painted. It is because of its body that it is used in paints of all colours, even black. It is often adulterated with sulphate of baryta, a fraud easily detected by dissolving a sample in nitric acid, in which the sulphate is insoluble.

The salts of lead are sweetish and metallic to the taste. In cases of poisoning with lead, the precipitates given in the Table will suffice to determine its presence. The black sulphuret which is thrown down when sulphuretted hydrogen is passed into solution of salts of lead, is very characteristic, and exceedingly delicate. The 100,000th part may, it is said, be detected in a neutral solution. Iodide and chromate of lead are very characteristic.

CHROMIUM.—Cr 28.

(395.) This metal is found in combination with oxide of iron in the Shetland Islands. The metal may be obtained by mixing oxide of chromium with one-fifth its weight of charcoal powder, and subjecting it to a very strong heat. It is a hard greyish-white brittle metal, specific gravity 5.9, and very difficult of fusion. Its name is derived from the Greek, and signifies colour. Many of its salts are coloured, and form useful dyes and pigments.

(396.) **Protoxide of Chromium**, CrO, is ob-

tained by adding pure potash to the protochloride. It falls as a brown hydrate, which speedily becomes red, hydrogen being disengaged. It is a powerful base, resembling the protoxide of iron, and forms pale blue salts, which absorb oxygen with great avidity.

(397.) DEUTOXIDE OF CHROMIUM, $Cr^3 O^4$, is the brown red compound above noticed. It corresponds with the magnetic oxide of iron, and is not salifiable.

(398.) SESQUIOXIDE OF CHROMIUM, $Cr^2 O^3$, is formed by heating chromate of mercury to redness; mercury and oxygen are evolved, and a pure green oxide remains. The hydrated sesquioxide may be obtained by adding small portions of sugar to a boiling solution of bichromate of potash, made strongly acid with hydrochloric acid; carbonic acid escapes, and the colour of the liquid changes from red to green; a slight excess of ammonia throws down the hydrate as a purplish green precipitate. Oxide of chromium communicates a fine green colour to glass, and is the colouring matter of the emerald.

(399.) PROTOCHLORIDE OF CHROMIUM, $Cr\,Cl$, is made by heating the sesquichloride to redness in a tube through which a current of dry and pure hydrogen is passed; hydrochloric acid is evolved, and a white mass is obtained, yielding a blue solution with water, and a great elevation of temperature. It greedily absorbs oxygen, passing into oxychloride of chromium, $Cr^2 Cl^2 O$. It is a powerful deoxidizing agent.

(400.) SESQUICHLORIDE OF CHROMIUM, $Cr^2 Cl^3$, may be obtained by passing chlorine over a mixture of oxide of chromium and charcoal; the sesquichloride sublimes, and is deposited in the cool portion of the tube, in crystalline plates of a pale violet colour. These are said to be quite insoluble in pure water, but dissolve with elevation of temperature in water containing a mere trace of the protochloride.

(401.) CHROMIC ACID, CrO^3, may be obtained nearly pure as follows:—Take 100 measures of cold saturated solution of bichromate of potash, add to this 120 to 150 measures of concentrated sulphuric acid; the mixture on cooling gradually deposits dark crimson needles of chromic acid; collect these, place them on a tile, and over them another tile or bell-jar; the chromic acid will be found quite dry after a little while, and nearly pure. Chromic acid is deliquescent and soluble; it is instantly reduced by contact with organic matter.

(402.) CHROMATE OF POTASH. KO, CrO^3.—Whenever oxide of chromium is heated with an alkali, chromic acid is formed. Chromate of potash is prepared directly from chrome iron ore, by roasting with nitre, or with carbonate of potash; the resulting chromate of potash is dissolved out and purified by crystallization. It is of a yellow colour, and has a cool, bitter, disagreeable, metallic taste, and dissolves in two parts of water at 60°.

(403.) BICHROMATE OF POTASH. $KO, 2CrO^3$.—When any acid is added to the preceding, and the solution set aside, one-half the base is removed, and bichromate of potash crystallizes out. It is largely manufactured, and appears as beautiful red crystals, derived from an oblique rhombic prism. It melts when heated, and is soluble in 10 parts of water.

(404.) **Chromate of Lead**, PbO, CrO^3, is formed when a solution of bichromate of potash is added to acetate or nitrate of lead. It is a brilliant yellow powder, insoluble in water; if the mixture be made in the cold, it contains one atom of water; if not, it is anhydrous, and of a darker colour. It is the *chrome yellow* of the painters and dyers.

By boiling this with lime-water half the acid is withdrawn, and an orange yellow subchromate is the result, which is also a valuable pigment.

TIN.—Sn 59.

(405.) The principal ores of this metal are the oxide and sulphuret. It occurs abundantly in Cornwall, whence it was obtained from a very early period by the Phœnicians. It appears that it was through the medium of the trade in tin that Christianity was first introduced into this country. —(See *Soame's Latin Church*, p. 30.)

Pure tin has a silvery white colour; it is soft and malleable; its specific gravity is 7.3, and it melts at 442°. It retains its lustre even when exposed to the action of air and water; it rapidly oxidizes when heated; it dissolves in hydrochloric acid; nitric acid acts on it with great violence, converting it into a white hydrate of the peroxide.

(406.) **Protoxide of Tin.** SnO.—When solution of protochloride of tin is mixed with carbonate of potash, a white hydrate of the protoxide falls, carbonic acid escaping; this is dried in an atmosphere of carbonic acid, in order to prevent access of air; it changes to a dense black powder, which is permanent in air, but burns like tinder into the peroxide on being heated. The hydrate dissolves in caustic potash, and partially decomposes into metallic tin and peroxide.

(407.) SESQUIOXIDE OF TIN, $Sn^2 O^3$, has been but little examined; it is produced by the action of hydrated protoxide of iron upon protochloride of tin.

(408.) PEROXIDE OF TIN. $Sn O^2$.—This substance is obtained in two states, possessing very different properties. The first modification, *a* $Sn O^2$, is prepared by precipitating the perchloride with an alkali; it then appears as a white bulky hydrate, freely soluble in acids: *b* $Sn O^2$, the other modification, is prepared by boiling bichloride with excess of nitric acid, or by acting directly on the metal; a white substance is produced, which does not dissolve in acids. Both these modifications dissolve in caustic alkalies, and are precipitated unchanged by an acid; the hydrates are both acid, and when ignited, yield pure peroxide of tin, of a yellow colour.

(409.) PROTOCHLORIDE OF TIN, $Sn Cl$, is prepared by dissolving tin in hydrochloric acid. It crystallizes in needles, containing 3 equivalents of water, which are apt to decompose in a dilute solution, except free hydrochloric acid be present. The anhydrous chloride may be prepared by distilling a mixture of tin filings and calomel. It is a very fusible substance, volatile at a high temperature; it is used as a deoxidizing agent.

(410.) PERCHLORIDE OF TIN. $Sn Cl^2$. — This was originally called the fuming liquor of Libavius. It may be made by the direct action of chlorine on tin, or by distilling 1 part of tin with 5 of corrosive sublimate; it is a thin colourless liquid, which boils at 248°. It is prepared in solution by dissolving tin in aqua regia, and is used by dyers as a mordaunt.

(411.) PROTOSULPHURET, $Sn S$, is prepared by fusing tin with sulphur.

BISULPHURET OF TIN. $Sn S^2$.—This is the mosaic gold; it is prepared by heating in a flask 12 parts of tin, 6 of mercury, 6 of sal ammoniac, and 7 of flowers of sulphur. Sal ammoniac, cinnabar and bichloride of tin sublime, leaving the bisulphuret in gold-coloured scales.

(412.) ALLOYS OF TIN.—Tin plate is iron covered with a surface of tin. The iron is made perfectly clean, and dipped into a bath of melted tin.

Pewter is a mixture of lead and tin, hardened with a little antimony.

TUNGSTEN.—W 100.

(413.) It is found in a mineral called wolfram, which is tolerably abundant in Cornwall. It is prepared by passing hydrogen over tungstic acid at a high heat. It is a white metal; specific gravity 17.4; hard, brittle, and infusible.

(414.) OXIDE OF TUNGSTEN, $W O^2$, is prepared as above, only taking care not to raise the heat above dull redness; it is a brown powder, which turns into tungstic acid; it is not salifiable.

(415.) TUNGSTIC ACID. $W O^3$.—When tungstate of lime can be procured, hot nitric acid will set the tungstic acid free. It is a yellow powder, insoluble in water, and dissolved by caustic alkalies.

MOLYBDENUM.—Mo 48.

(416.) This metal is found in Bohemia, Sweden, and Cornwall, as a sulphuret. It is a white brittle metal, very infusible; specific gravity 8.6. It may be obtained in the metallic state by heating molybdic acid with charcoal.

(417.) **Protoxide of Molybdenum**, MoO, is made by putting a piece of zinc into the hydrochloric solution of molybdic acid; the liquid changes to blue, red, and black; when ammonia in excess throws down a black hydrated oxide.

(418.) **Deutoxide of Molybdenum**, $Mo\,O^2$, is prepared as above, copper being substituted for zinc: excess of ammonia precipitates the deutoxide, dissolving the oxide of copper. It appears in the form of a dark brown powder.

(419.) **Molybdic Acid.** $Mo\,O^3$.—The native sulphuret is roasted at a red heat, and the impure molybdic acid dissolved in ammonia; the filtered solution is then evaporated to dryness, purified by repeated solution, and decomposed by heat. Molybdic acid is a yellow powder, fusible at a red heat, and sparingly soluble in water.

VANADIUM.—V 68.

(420.) This metal, named from Vanadis, a female deity of Scandinavia, is found in small quantity in the Swedish iron ores. It may be prepared by passing dry ammoniacal gas into the liquid chloride of vanadium, and then exposing the resulting saline mass to heat. Sal ammoniac volatilizes, and vanadium remains; it is a white brittle metal, very infusible.

(421.) Protoxide of Vanadium, VO, is prepared by passing hydrogen over heated vanadic acid. It is of a black colour, conducting electricity, and not salifiable.

(422.) Deutoxide of Vanadium, VO^2, may be prepared by heating together 10 parts of protoxide, and 12 of vanadic acid. It is salifiable; of a black colour.

(423.) Vanadic Acid. VO^3. — The native vanadiate of lead is dissolved in nitric acid; the lead and arsenic precipitated with sulphuretted hydrogen, the vanadic acid being reduced at the same time to deutoxide. The blue solution is evaporated to dryness, by which the vanadic acid is reproduced; it is then dissolved out by ammonia; into the solution a lump of sal ammoniac is placed, which precipitates the vanadiate of ammonia, which is insoluble in saline solutions; this is washed, dried, and heated below redness, in an open crucible; vanadic acid is left as a dark red powder, fusible below redness, dissolving sparingly in water, and more readily in acids. It forms red salts with alkalies.

(424.) Chlorides of Vanadium.—The bichloride is brown; the perchloride is made by passing chlorine over a mixture of protoxide of vanadium and charcoal; it is a yellow liquid.

TANTALUM, OR COLUMBIUM.—T 185.

(425.) This metal is prepared from a rare mineral, tantalite, and yttrotantalite. The metal is obtained by heating the double fluoride of tantalum and potassium with potash; it is a grey metal, not much acted on by acids, and burning into tantalic acid when heated with potash.

(426.) **Binoxide of Tantalum**, TO^2, is prepared by heating tantalic acid to whiteness with charcoal; it is a dark brown powder, insoluble in acids.

(427.) **Tantalic Acid**, TO^3, is formed by heating the ores of tantalum with carbonate of potash; tantalate of potash is formed, which is precipitated with a stronger acid.

NIOBIUM AND PELOPIUM.

(428.) The oxides of these metals exist in the tantalite of Bohemia; they resemble the above; when hot, tantalic acid remains white, while pelopic acid becomes yellowish, niobic acid dark yellow.

TITANIUM.—Ti 24.

(429.) This metal is sometimes found in the slags of the iron furnaces of Merthyr Tydvil, in small cubic crystals, of a coppery colour, very hard, and infusible. There is an oxide of titanium, which has not been examined. The best known of its compounds is titanic acid, TiO^2.

(430.) **Titanic Acid.** TiO^2.—Titaniferous iron ore is reduced to powder, and fused with 3 parts of carbonate of potash; the product is washed with water, and the residue dissolved in hydrochloric acid; on dilution with water, and boiling, titanic acid is precipitated; it very much resembles silica.

(431.) **Bichloride of Titanium** is a colourless volatile liquid, obtained by passing chlorine over titanic acid and powdered charcoal, at a red heat.

ANTIMONY.—Sb 129.

(432.) The principal ore of antimony is a sulphuret; it is freed from impurities by melting, and then is decomposed by heating with iron filings, which abstract sulphur. If required very pure, its oxide should be reduced with charcoal and alkali. It is of a bluish white colour, extremely brittle. Specific gravity 6.8; and it melts at a temperature just short of redness; at a white heat it boils. It is difficult to cast in this metal, as it solidifies so rapidly, that it often does not reach the bottom of the mould. When castings are required for the thermo-electric battery, they may be procured by keeping the metal at a full red heat. It retains its lustre at common temperatures, but oxidizes at a red heat. When strongly heated, it burns with a white flame, producing oxide. It is dissolved by hot hydrochloric acid, with evolution of hydrogen and production of chloride.

(433.) OXIDE OF ANTIMONY, SbO^3, is made by burning antimony. Thus prepared, it is obtained in brilliant crystals. It is white, fusible at a red heat, and volatile in close vessels; but in contact with air, absorbs oxygen, being converted into antimonious acid; boiled with acid tartrate of potash, it yields the double tartrate of antimony and potash, which is used in medicine under the name of tartar emetic.

(434.) ANTIMONIOUS ACID. $Sb\,O^4$.—This is the ultimate product of the action of heat and air on the metal. It is greyish-white and insoluble, except when recently precipitated; it combines with alkalies, forming salts.

(435.) ANTIMONIC ACID, $Sb\,O^5$, is produced when antimony is acted on by strong nitric acid. It is thus obtained as an insoluble hydrate, which, on drying carefully at 500°, becomes anhydrous. It is of a pale yellow colour, tasteless, and insoluble in water, yet reddening moistened litmus.

(436.) TERCHLORIDE OF ANTIMONY, $Sb\,Cl^3$, is produced by dissolving the sulphuret in hydrochloric acid. The impure and acid solution is then put into a retort and distilled. When the liquid which falls from the beak of the retort gives a white precipitate in the aqueous liquid of the receiver, the receiver must be changed, and into it pure chloride of antimony distils and solidifies on cooling into a white crystalline mass: air must be excluded. It is very deliquescent. It deposits a white powder when its solution in hydrochloric acid is put into water. This is an oxychloride.

(437.) PERCHLORIDE OF ANTIMONY, $Sb\,Cl^5$, is made by passing dry chlorine over heated metallic antimony. It is a volatile liquid which fumes in the air.

(438.) SULPHURET OF ANTIMONY. $Sb\,S^3$.—This is the ore of antimony, and is sometimes called crude antimony. It occurs in radiated crystalline needles, and may be prepared artificially by melting together sulphur and antimony. When a solution of tartar emetic is precipitated with sulphuretted hydrogen, a brick-red precipitate falls. From this by a gentle heat water may be expelled, when it retains its colour; at a higher temperature, it assumes the aspect and colour of the native sulphuret. It is a sulphur acid.

(439.) PERSULPHURET OF ANTIMONY, $Sb\,S^5$, may be formed by passing sulphuretted hydrogen through antimonic acid diffused in water. It is an orange-coloured powder.

(440.) ANTIMONIURETTED HYDROGEN.—A combination of antimony with hydrogen exists. When zinc is put into a solution of oxide of antimony, and sulphuric acid added, the hydrogen combines with the antimony. It deposits antimony on standing over water.

(441.) James's powder owes its activity to oxide of antimony: it is a useful medicine. With lead, antimony forms type metal. The alloy is hard, and expands in cooling, so as to form very sharp castings: both lead and antimony when alone make very bad ones.

TELLURIUM.—Te 64.

(442.) This metal is scarce, but interesting, as adding another member to the group which connects the metals and semi-metals. The metal is most readily obtained from the sulphotelluret of bismuth. The ore is powdered, mixed with an equal weight of carbonate of soda, made into a paste with oil, and exposed to a high white heat. Telluret and sulphuret of sodium are formed, and bismuth set free; the fused mass is then dissolved in water, and exposed to air, when the sulphur and sodium oxidize, and tellurium separates in the metallic state. Tellurium is of a tin-white colour, fusible at a temperature a little above that of melting lead; volatile at a red heat into a yellow vapour. Specific gravity 6.3.

(443.) TELLUROUS ACID, $Te\,O^2$, is obtained by burning tellurium. It is feebly soluble in water and acids. It forms crystallizable salts with alkalies. Hydrate of tellurous acid is thrown down when nitric acid is added in slight excess to tellurite of potash. It is white, soluble in water, and reddens litmus.

(444.) **Telluric Acid**, $Te\ O^3$, may be obtained by passing chlorine through a solution of tellurous acid in excess of potash. Chloride of barium is then added in small quantity, to precipitate any sulphuric acid which may happen to be present. To the filtered liquor ammonia is added to saturation, and then chloride of barium. Tellurate of baryta falls, which is then digested with one-fourth its weight of sulphuric acid; the resulting solution yields crystallized telluric acid. It is freely, though slowly, soluble in water. When heated, it loses water, and then becomes of a yellow colour, insoluble in water, and even in boiling alkaline solutions. The tellurates of the alkalies are soluble; those of the earths nearly or quite insoluble. There is a combination of this metal with hydrogen resembling sulphuretted hydrogen.

ARSENIC.—As 75.

(445.) This metal is sometimes found native, but much more commonly in combination with other metals. The largest portion used in commerce is derived from roasting the arsenurets of iron, cobalt, and nickel. These ores are roasted, and the arsenic condensed in a long chimney. The crude arsenious acid thus produced is purified by a second sublimation. The metal may be obtained by heating the white arsenic of commerce with charcoal mixed with a little alkali.

This metal has a steel-grey colour, and is brittle and crystalline; specific gravity 5.7. It tarnishes in air, but may be preserved unchanged in pure water. It is volatile, rising in vapour before it fuses. It smells like garlic.

(446.) ARSENIOUS ACID. AsO^3.—This is the ordinary white arsenic of commerce. There are two varieties; the vitreous acid, which is glassy in appearance, and the opaque white acid. These seem to have different solubility; the glassy changes spontaneously into the opaque by keeping. 100 parts of water at 60° dissolve rather less than 1 part of vitreous, and rather more than 1 part of opaque acid. It unites with bases, forming salts for the most part uncrystallizable when soluble. It is a fearful poison, causing terrible pain when administered. It is, on account of its cheapness and the ease with which it is procured, sometimes used with a felonious intent; fortunately, however, the arsenic can always be detected by unfailing tests.

(447.) ARSENIC ACID, AsO^5, may be procured by acting on the hydrochloric solution of arsenious acid with nitric acid; the whole being then cautiously evaporated to dryness; an anhydrous acid is the result. It is slowly, but entirely soluble in water, giving an acid solution, and very poisonous. At a high temperature it is converted into arsenious acid.

Arsenic acid much resembles the phosphoric acid, and, like it, is bibasic. Thus, ordinary arseniate of soda is $2\,NaO, HO, AsO^5 + 24\,HO$, which in appearance resembles common phosphate of soda. There is another, $3\,NaO\ AsO^5 + 24\,HO$, and $NaO\ 2\,HO\ AsO^5 + 2\,HO$; the former being produced by adding excess of base, and the other, excess of acid. Those alkaline arseniates which contain basic water lose it at a red heat, but recover it when re-dissolved. In this respect they differ from the phosphates. The salts of the alkalies are soluble in water; those of the earths are insoluble, and dissolve in acids. Nitrate of silver gives a very characteristic reddish-brown precipitate.

(448.) PROTOSULPHURET OF ARSENIC, REALGAR, $As S^2$, occurs native; it may be formed artificially by heating sulphur and arsenic. It is a red, fusible, and volatile substance. It is used in white fire, which consists of 24 parts nitre, 7 sulphur, 2 realgar.

(449.) YELLOW SULPHURET OF ARSENIC, ORPIMENT, $As S^3$, is formed by fusing arsenious acid with excess of sulphur. It is a golden-yellow substance, fusible and volatile. It is also formed when sulphuretted hydrogen is passed through a solution of arsenious acid.

(450.) PERSULPHURET, $As S^5$, is produced when sulphuretted hydrogen is passed into a solution of arsenic acid. It is yellow and fusible, and may be sublimed in close vessels without change.

(451.) CHLORIDE OF ARSENIC, $As Cl^3$, is made by passing dry chlorine over arsenic. It is an oily liquid, volatile, and resolved by water into hydrochloric and arsenious acids.

(452.) IODIDE OF ARSENIC, $As I^3$, is made by fusing iodine with arsenic. It is a deep-red crystalline substance, and volatile. Its vapour is remarkably heavy.

(453.) ARSENURETTED HYDROGEN, $As H^3$, is produced when nascent hydrogen comes in contact with arsenic or its compounds. Equal parts of zinc and arsenic are melted together and acted on by strong hydrochloric acid. Arsenuretted hydrogen is disengaged, having a strong odour of garlic. Its specific gravity, compared with air, is 2.695. It is a fearful poison; a few bubbles being inhaled, have caused death. Gehlen and Bullake died from its effects after an illness of nine and twelve days respectively.

(454.) *Tests for Arsenic.*—The form in which this is administered is usually that of arsenious acid, and has often, in cases of poisoning, to be extracted either from the stomach of the deceased, or from some fluid or food which has been administered. The object generally is, if possible, to produce an unmistakeable quantity of metallic arsenic.

If the arsenic can be detected as a white powder at the bottom of the vessel, as is often the case, then the following methods will put its nature beyond a doubt:—

Wash the powder with cold distilled water, dry it, and then put it at the bottom of a test tube, with splinters of charcoal above it; apply heat, and the arsenious acid will be reduced, and settle as a grey metallic film on the cool part of the tube; the arsenic will be recognised by the odour of garlic.

Convert the arsenic into arsenious acid by heating it gently with a spirit-lamp; wash it out of the tube, and add nitrate of silver. No precipitate, or only a faint cloud, is produced until a drop of ammonia is added, when a yellow precipitate falls, very soluble in excess.

To another portion of the liquid add a solution of sulphate of copper. No precipitate till a little alkali is added, when a brilliant yellow-green precipitate falls. Soluble in excess of ammonia. This is known as Scheele's green.

To another portion add a few drops of hydrochloric acid, and pass sulphuretted hydrogen through it. The yellow sulphuret of arsenic falls. Soluble in ammonia, and again precipitated by acids.

These tests together demonstrate the presence of arsenious acid.

Bright copper placed in a solution of arsenious acid, acidulated with hydrochloric acid, is covered with a white alloy. On again heating the copper, the arsenic sublimes.

Marsh's test. The suspected liquid is acidulated wth sulphuric acid, and placed in contact with zinc. Arsenuretted hydrogen rises, which may be burnt. On a cool glass plate being held in it, a ring of arsenic makes its appearance. It is to be remembered, that the zinc and sulphuric acid of commerce often both contain arsenic, and therefore must be ascertained to be pure before this test can be applied. Antimony displays a like reaction.

MERCURY.—Hg 100.

(455.) This metal occurs native; its principal ore is a sulphuret. It is easily reduced to the state of metal from the sulphuret by heating with lime or scales of iron. It is a brilliant white metal, fluid at common temperatures; specific gravity, 13.568. It boils when heated to 656_{o}, and its vapour is quite transparent, and about seven times as heavy as air. At 39° below 0 it freezes, and is then malleable.

Mercury combines with oxygen in two proportions, forming a dinoxide and a protoxide, both of which are salifiable.

(456.) **Dinoxide of Mercury. Black Oxide,**

$Hg^2 O$.—This is sometimes called the protoxide, the equivalent of mercury being doubled. It is prepared by precipitating dichloride of mercury diffused in water, by excess of potash. It is very unstable, light converting it into protoxide and metal. It is salifiable.

(457.) Protoxide of Mercury. Red Oxide of Mercury, $Hg O$.—This oxide is prepared by exposing mercury to heat in a flask with a long neck. The temperature is kept just below the boiling point; the long neck prevents the escape of vapour, at the same time that it admits air. The mercury gradually oxidates into a reddish brown powder. It is a strong base, sparingly soluble in water, and the solution changes violet to green. It has an acrid metallic taste, and is poisonous. At a heat below redness it evolves oxygen. It is sometimes adulterated with red lead—a fraud which may be detected by placing a sample upon a red-hot iron, when it is entirely evaporated if pure; if not, the red lead remains.

(458.) Dichloride of Mercury. Calomel, $Hg^2 Cl$.—This may be prepared by adding mercury to corrosive sublimate; 4 of corrosive sublimate are mixed with 3 parts of mercury until the globules disappear; the mixture is then heated, and the subchloride rises; it should be largely washed with hot distilled water. Calomel should be perfectly colourless and tasteless. It is insoluble in water; at a heat below redness it rises in vapour. It is much used in medicine.

(459.) Chloride of Mercury. Perchloride of Mercury. Corrosive Sublimate, $Hg Cl$.—The ordinary process consists in exposing a mixture of chloride of sodium and sulphate of mercury to heat; double decomposition ensues, chloride of mercury sublimes, and sulphate of soda remains in the retort. Corrosive sublimate occurs as a white powder, or in white semitransparent masses. It is soluble in 16 parts of cold and 3 of hot water, and the solution deposits quadrangular crystals as it cools. It has an acrid, nauseous, metallic taste, and is very poisonous. Excess of potash throws down a yellow hydrated oxide; if, however, the chloride be in excess, an oxychloride of a brown colour, consisting of $Hg\,Cl\,Hg^3\,O$ is precipitated.

(460.) Subiodide of Mercury, $Hg^2\,I$, may be formed by rubbing together in a mortar 2 equivalents of mercury with 1 of iodine. It is a dirty-yellow powder.

(461.) Iodide of Mercury, $Hg\,I$, may be formed by precipitating the chloride with iodide of potassium. Care must be taken to use equivalent proportions of both the salts, as the iodide is soluble in corrosive sublimate and also in iodide of potassium. It is of a brilliant red colour; heated, it fuses into a yellow liquid, which rises in vapour, condensing into brilliant yellow crystals; if in this state it be scratched with a hard body, it gradually becomes red, the form of the crystals changing. This is a most curious instance of dimorphism. It is used as a pigment, and is called permanent scarlet—a name it hardly deserves.

(462.) Subsulphuret of Mercury, $Hg^2\,S$, is precipitated as a black powder when sulphuretted hydrogen is passed through solution of the subnitrate. Heat resolves it into sulphuret of mercury and metal.

(463.) Sulphuret of Mercury. Cinnabar. Vermilion, $Hg\,S$, is made by heating together

6 parts of mercury and 1 of sulphur, and reducing to powder the resulting cinnabar; the beauty of the tint depending much on the extent to which the division is carried. It is used as a paint. The black sulphuret obtained by precipitating corrosive sublimate with sulphuretted hydrogen, may be converted into cinnabar without change of composition by sublimation, or by heating it in a solution of pentasulphuret of potassium.

Native cinnabar is the most common ore of mercury; it is of various colours, from steel-grey to bright red.

(464.) NITRATES OF THE OXIDES OF MERCURY.—Several salts are formed according to the temperature and state of dilution of the nitric acid; cold and slightly diluted acid forms salts of the grey oxide; when hot and concentrated, of the red; both classes are apt to be decomposed by considerable quantity of water, giving rise to insoluble basic salts.

(465.) SULPHATE OF SUBOXIDE OF MERCURY falls when sulphuric acid is added to solution of subnitrate; it is sparingly soluble in water.

(466.) SULPHATE OF THE RED OXIDE is prepared by boiling together equal weights of sulphuric acid and mercury, the whole being evaporated to dryness; the salt is then $HgO\,SO^3$. Water decomposes this, forming a compound known formerly as *Turpeth mineral;* it is a subsulphate, Hg^2O, SO^3. Long continued washing makes it more and more basic.

(467.) The salts of mercury are easily recognised; they are all either volatile or decomposed at a red heat; those which are volatile may be decomposed by heating in a test tube with dry carbonate of soda. Copper precipitates mercury from the soluble salts; the hydrated oxide is thrown down by potash and soda from its soluble salts, and is very characteristic.

(468.) The alloys of mercury with the metals are called amalgams; some of them are definite compounds, and can be made to crystallize. The amalgam of tin is used for silvering looking-glasses. For this purpose a piece of the foil is laid on the glass, and then quicksilver poured over and rubbed in by a ball of flannel or cotton; mercury is still poured on till it shows a tendency to run off; the glass is then slightly inclined, so as to let the excess run off, and also to allow the mercury to come, as it were, between the glass and the tin-foil; it is then again laid on a very gentle incline, and weighted. After a few days, the mercury and tin form a strong amalgam, which adheres to the glass; it is then raised into a perpendicular position, and the excess of mercury drains away.

(469.) **FULMINATING MERCURY. FULMINATE OF MERCURY**, $2\,Hg^2, O, Cy^2\,O^2$. — Dissolve 100 grains of mercury in a measured ounce and a half of strong nitric acid, aided by heat; when cool, this is to be poured into two measured ounces of spirit of wine, specific gravity 0.833, gently heated till action commences; if the effervescence becomes violent, it must be stopped by cooling the vessel, or adding cold alcohol. A yellowish grey precipitate falls, which is to be separated, washed, and dried below 100°. This substance is in considerable demand for percussion caps. It is to be mixed with a little tincture of benzoin sufficient to moisten it and dropped into the caps. It is dangerously explosive. The late Mr. Hennell was literally blown to atoms by the explosion of 6 pounds of this substance; it requires, therefore, the greatest caution in handling.

SILVER.—Ag 108.

(470.) This metal has been known from the earliest ages; it is sometimes found native. The commonest ore is a sulphuret, and it is frequently associated with galena.

(471.) Silver is usually obtained by a process called amalgamation; its ores are too poor to be submitted to any process of smelting. The ore is crushed to powder, mixed with common salt, and roasted; by this means the silver is reduced to the state of chloride. The roasted ore is then put into a barrel with scraps of iron and both are agitated together, by which the chloride of silver is reduced to the state of metal; this is then agitated with mercury, which forms a fluid amalgam with the silver, together with any gold and copper which may happen to be present in the ore. The mercury is then driven off by heat, and the silver left behind in an impure state.

(472.) There is a little silver in almost every specimen of galena. When this proportion rises above a certain amount it pays for extraction. The ore is reduced in the usual manner, the silver remaining with the lead; it is then re-melted, and allowed partially to solidify. The alloy of silver and lead is more fusible than pure lead, and accordingly that part which solidifies first is nearly pure lead, while the silver is retained in the liquid portion, which is poured off; this process may, if necessary, be repeated more than once. The lead now rich in silver is melted in a furnace, in which a blast of air is allowed to play over the surface of the metal; this sweeps away the oxide of lead, which is gradually formed; and when the whole of the lead has thus been nearly got rid of, the residue is transferred to a *cupel*, or shallow dish made of bone earth, which absorbs the oxide of lead as it is formed, leaving the silver bright and pure.

(473.) Pure silver may be obtained by dissolving the alloy used for plate or coin in nitric acid, precipitating with common salt, and washing the white curdy precipitate of chloride. This must be dried, put into a crucible with about twice its weight of carbonate of soda, and heated nearly to whiteness; a button of pure silver will be found at the bottom of the crucible.

Pure silver has a brilliant white colour, is a most excellent conductor of heat and electricity; its specific gravity is 10.5; in hardness it lies between gold and copper; it melts at a bright red heat or at 1873°. It is not acted on by air or moisture: the tarnish of plated articles is due to sulphuretted hydrogen; hence the reason why plate tarnishes in a house where there are bad smells, or where imperfectly purified gas is allowed to escape. At a red heat it absorbs oxygen from the atmosphere, giving it out again as it solidifies; a small proportion (less than two per cent.) of copper prevents this. Boiling oil of vitriol converts it into sulphate of silver; nitric acid dissolves it readily even in the cold.

(474.) SUBOXIDE OF SILVER. Ag^2O.—When dry citrate of silver is heated to 212° in hydrogen gas it loses oxygen, and becomes brown. Dissolved in cold water, a solution of citrate of the suboxide and citric acid is obtained, from whence the suboxide may be precipitated by potash as a black powder, soluble in ammonia.

(475.) **Protoxide of Silver.** AgO.—Caustic potash throws down from nitrate of silver a pale brown precipitate which is protoxide; it is soluble in ammonia, and to a slight extent in water; the solution is alkaline; it is a powerful base isomorphous with potash, soda, and ammonia.

(476.) **Peroxide of Silver** is obtained by means of the galvanic battery. It is a black powder, reduced by heat; it explodes with phosphorus when struck.

(477.) **Chloride of Silver,** $AgCl$, is produced by adding a soluble chloride to any soluble salt of silver except the hyposulphite. It falls as a white curdy precipitate, insoluble in water and nitric acid, which blackens by exposure to light; the presence of organic matter greatly accelerates this change; it is reduced when put into water with zinc or iron. Boiled with caustic potash, protoxide of silver is the result. It is soluble in ammonia, and in cyanide of potassium.

(478.) **Iodide of Silver,** AgI, is produced by adding nitrate of silver to iodide of potassium. It is a yellow powder, insoluble in ammonia, thus forming an exception to most of the salts of silver. Bromide of silver resembles the chloride.

(479.) **Nitrate of Silver,** $AgONO^5$, is prepared by dissolving silver in nitric acid; it crystallizes in transparent anhydrous tables, soluble in their own weight of cold and half their weight of boiling water. They fuse when heated; and the fused nitrate cast into moulds is known as lunar caustic. It blackens when exposed to light. It is the indelible marking ink used for marking linen. The black stain is supposed to be due to reduced silver.

(480.) SULPHATE OF SILVER, $AgOSO^3$, is prepared by boiling silver in sulphuric acid; it dissolves in 88 parts of hot, and is nearly insoluble in cold water. It forms a crystallizable compound with ammonia, freely soluble in water, containing $AgOSO^3 + 2NH^3$.

(481.) SULPHURET OF SILVER is found native; it may be prepared by heating together sulphur and silver; it is a grey substance, and is a sulphur base.

(482.) When precipitated oxide of silver is digested in ammonia, a dangerously explosive substance is produced. It explodes while moist if rubbed by a hard body; when dry the touch of a feather is sufficient.

(483.) *General Character of the Salts of Silver.*—The salts of silver are recognised by a white curdy precipitate with a soluble chloride, darkening by exposure to light. Solutions of silver are reduced to the metallic state by iron, copper, and mercury. Nitrate of silver is kept in the laboratory as a test for chlorine and chlorides. The liquid to be examined should be acidulated with nitric acid, and excess of nitrate of silver added, and the precipitate dried and fused; the proportion of chlorine is then known, for chloride of silver consists of—

	Atoms.	Weight.	per Cent.
Silver	1	108	75
Chlorine	1	36	25
Chloride of Silver	1	144	100

(484.) *Alloys of Silver.*—Standard silver, which is used for plate, is composed of 11.10 parts silver and .9 copper; or a pound troy is composed of 11 oz. 2 dwts. silver and 18 dwts. copper. A shilling weighs 3 dwts. 15.27 grs., of which 3 dwts. 8¼ grs. are pure silver.

GOLD.—Au 200.

(485.) Gold has been known from the remotest ages. It occurs in nature in a metallic state, alloyed with silver and copper. It is found in Peru, Brazil, Mexico, and California, the west coast of Africa, in Europe in Transylvania and Hungary, and in the Ural Mountains in Asia.

Gold may be obtained pure by dissolving standard gold of commerce in aqua regia, composed of 1 part by weight of nitric and 2 hydrochloric acid, evaporating to dryness, redissolving and filtering, and then adding a solution of protosulphate of iron. The gold precipitates as a brown powder, which may be fused into a yellow button. The protosulphate of iron is a very delicate test for gold, producing a blue tint in a solution, containing not more than a 60,000th of the metal.

Gold is of a deep yellow colour, fusible at a bright red heat; its specific gravity is 19.2, which by hammering becomes 19.6; it is very malleable, a single grain may be made to cover 56.39 inches, and drawn out into 500 feet of wire. It is not affected by air and moisture, nor by the pure acids. Aqua regia is its best solvent. It is probably the chlorine, however, which is the active agent; iodine and bromine also act upon it.

(486.) **Protoxide of Gold**, AuO, is prepared by precipitating the protochloride with potash. It is of a violet colour, or when in the hydrated state nearly black. At 480° it loses oxygen.

(487.) **Peroxide of Gold, Auric Acid**, AuO^3, is prepared by precipitating the perchloride by magnesia, washing with very dilute nitric acid, and drying at a very low heat; it is reduced by heat and exposure to light. It unites with bases, and possesses feeble acid properties; digested with ammonia it forms fulminating gold. It is a reddish yellow powder.

(488.) **Protochloride of Gold.** $AuCl$.—The perchloride is evaporated to dryness, and exposed to a heat of 440°; chlorine is evolved. It is yellowish white, insoluble in water, but resolved by that fluid, especially when hot, into metallic gold and perchloride.

(489.) **Perchloride of Gold**, $AuCl^3$, is produced by dissolving gold in aqua regia; the solution is yellow. If this be evaporated to dryness, and cautiously heated, hydrochloric acid is expelled, and a red deliquescent crystalline mass of perchloride of gold remains. The taste of this substance is nauseous, acrid and metallic; and it is apparently as poisonous as corrosive sublimate.

(490.) *General Character of the Salts of Gold.*—The salts of gold are characterized by giving a precipitate of metallic gold as a brown powder, with protosulphate of iron, a black precipitate with nitrate of suboxide of mercury, and their behaviour with protochloride of tin. The only important alloy of gold is that with copper; it is of this that gold plate and coin are made; the proportion is 11 gold to 1 copper. A sovereign weighs 5 dwts. 3.27 grains, of which 4 dwts. 17 grs. are fine gold.

Purple of cassius is made by adding chloride of gold to dilute solution of protochloride of tin; it is a purple powder, which is used in enamel painting.

PLATINUM.—Pt 99.

(491.) This useful metal is found in the Ural Mountains, in Ceylon, and a few other places; it occurs native, alloyed with one or more of the metals which will be next described. Pure platinum may be prepared from the crude ore as follows. Dissolve in aqua regia, pour off the resulting yellowish-red solution, and to it add sal ammoniac as long as a yellow precipitate falls; wash and dry, and expose to a red heat. Spongy platinum is left; this is made into a paste with water, put into a mould, and gradually but strongly pressed; it must be then dried strongly, heated to whiteness, and hammered; by this means the minute grains are welded together, and a bar may be formed, which can be forged, rolled into plates, or drawn into wire. Platinum is a whitish metal, very malleable and ductile, infusible in ordinary furnaces; specific gravity, 21.5; being the heaviest known substance; neither air, moisture, nor the ordinary acids act upon it at any temperature; hence its use for chemical vessels. It is one of the three metals that can be welded.

(492.) Platinum Black. — Ammoniochloride of platinum is mixed with dilute hydrochloric acid, and pure zinc put in the mixture; a dark powder falls, which must be washed with dilute nitric acid. It is then metallic platinum, and possesses the property of absorbing oxygen and other gases. When placed in a mixture of oxygen and hydrogen gases it causes their union, with elevation of temperature, sometimes sufficient to explode them.

(493.) **Protoxide of Platinum.** PtO.—When protochloride of platinum is digested with caustic potash, a black powder, soluble in excess, is produced, which is protoxide; it is a feeble base.

(494.) **Peroxide of Platinum.** PtO^2.—Add nitrate of baryta to persulphate of platinum; double decomposition takes place, and pernitrate of platinum is produced. Caustic soda precipitates one-half of the oxide of platinum; the hydrate is brown; the pure peroxide nearly black. It dissolves in acids, and combines with bases; digested in ammonia, it forms a fulminating compound. These two oxides are both reduced by heat.

(495.) **Protochloride of Platinum,** $PtCl$, is prepared by heating the perchloride to 400°. It is a greenish-grey powder, insoluble in water, soluble in hydrochloric acid. It is decomposed by heat into chlorine and platinum.

(496.) **Perchloride of Platinum,** $PtCl^2$, is formed by dissolving platinum in aqua regia. The acid solution on evaporation to dryness yields a red-brown residue, deliquescent, and soluble in water. It has an orange-yellow tint in solution.

(497.) **Ammoniobichloride of Platinum,** $NH^4Cl + PtCl^2$, falls as a yellow powder when bichloride of platinum is added to sal ammoniac. It is sparingly soluble, requiring 150 parts of cold, and 80 hot water.

(498.) **Potassiobichloride of Platinum,** $KaCl\ PtCl^2$, very much resembles the above. It is produced by using chloride of potassium instead of sal ammoniac. It is sparingly soluble in water; the corresponding sodium salt is soluble.

(499.) When ammonia in excess is added to the protochloride of platinum a green insoluble salt separates after a time. It is not affected by hydrochloric or sulphuric acids, or even boiling hot solution of potash. It contains the elements of protochloride of platinum and ammonia. When this is heated with concentrated nitric acid, it is converted into a white crystalline solid, which is soluble in water. It consists of $PtCl\,N^2H^6O + NO^5$; in which $PtCl\,N^2H^6$ acts as a metal, and its oxide as a salifiable base; it has not hitherto been insulated.

(500.) Perchloride of platinum is used as a test for potash; for this purpose the salts must be converted into chlorides. Sodiochloride is then added in crystals, and the whole dissolved in water; when the action is complete, alcohol is added, the precipitate collected, washed, dried and weighed. 100 potassiochloride correspond to 35 parts of chloride of potassium; of course the potassiochloride of platinum is equally characteristic of the presence of that metal.

(501.) Platinum crucibles are very useful. They should when used be always protected by being put into a common earthen crucible. They are injured, however, and even destroyed, (1.) if free chlorine is evolved in them; (2.) if nitre and caustic alkalies are fused in them; (3.) if fusible metals are reduced (as then the reduced metal generally combines with the crucible); (4.) if phosphorus or sulphur be evolved.

An alloy of 7 parts platinum, 16 copper, 1 zinc, is said to form a compound very much resembling gold.

PALLADIUM.—Pd 54.

(502.) This metal is found associated with platinum. The crude ore is heated, as above directed for platinum; and the solution which remains after the ammoniochloride has been precipitated is neutralized with carbonate of soda, and then cyanide of mercury is added. Cyanide of palladium precipitates as a whitish insoluble substance, which is washed, dried and heated, and spongy palladium is the result. It is then reduced to the malleable state, by the same process as platinum.

Palladium is a white metal, much resembling platinum; very infusible; specific gravity, 11.8. Hence it is at once distinguished from platinum by its inferior specific gravity. It is slowly attacked by nitric acid, and dissolves in aqua regia. It becomes superficially oxidated when heated.

(503.) Protoxide of Palladium, PdO, is obtained by dissolving in nitric acid, evaporating to dryness, and heating cautiously. It is black. The hydrate is thrown down when carbonate of soda is added to the nitrate; it is brown. This oxide is reduced by heat.

(504.) Peroxide of Palladium, PdO^2, is prepared by adding caustic potash slowly to the double chloride of potassium and palladium. It is then obtained as a yellowish powder, which contains water and alkali.

(505.) Protochloride of Palladium, $PdCl$, is obtained by dissolving palladium in aqua regia, and evaporating to dryness. It forms double salts. The ammonio and potassio-chlorides are a dirty-yellow colour, more soluble than the corresponding platinum compounds.

(506.) **Perchloride of Palladium** only exists in solution and in combination with alkaline chlorides. It is formed when the metal is digested in aqua regia. It forms a red potassiobichloride with chloride of potassium.

(507.) The cyanide is too characteristic to be mistaken.

(508.) An alloy of 6 gold and 1 part palladium, is used for the circle on which the divisions are engraved on the large mural circle at Greenwich.

RHODIUM.—R 52.

(509.) The residue obtained on extracting the last metal is mixed with hydrochloric acid, and evaporated to dryness; the residue is heated with spirit, specific gravity .837, which dissolves everything, except the double chloride of sodium and rhodium. This is dried, heated to whiteness, and rhodium in a coherent spongy mass remains, mixed with chloride of sodium, which is dissolved out by water.

Rhodium is a white brittle metal, specific gravity 11. None of the acids act on this metal, except it be alloyed with platinum.

(510.) **Oxide of Rhodium,** R^2O^3, is formed by heating rhodium with hydrate of potash and nitre in a silver crucible; oxide of rhodium in combination with potash is formed; this is removed with hydrochloric acid. It is a greenish grey insoluble hydrate.

(511.) **Chloride of Rhodium,** R^2Cl^3, is prepared by adding fluosilicic acid to the double chloride of potassium and rhodium, filtering and evaporating. It is a brownish red deliquescent mass. The double chloride of rhodium and potassium is red.

IRIDIUM.—Ir 99.

(512.) This metal is found in the insoluble residue after acting on the crude ore with aqua regia. It consists of an alloy of iridium and osmium. Heat this in a tube with chloride of sodium, through which moist chlorine is passed; chloride of iridium and sodium remains, and chloride of osmium sublimes. This is dissolved in water, and mixed with excess of carbonate of soda, and heated to whiteness; reduced by hydrogen and treated with hydrochloric acid to get rid of iron, which often adheres. Iridium remains as a powder, fusible with great difficulty by the oxy-hydrogen blow-pipe. It is a brittle metal.

(513.) There are four oxides of iridium—$Ir O$, $Ir^2 O^3$, $Ir O^2$, and $Ir O^3$; and four chlorides of similar constitution.

RUTHENIUM.—Ru 51.

(514.) This metal has been lately discovered associated with iridium, which it much resembles.

OSMIUM.—Os 100.

(515.) The volatile chloride mentioned above is passed into ammonia, it is decomposed, osmic and hydrochloric acids result, which combine with ammonia. This is heated in a closely stoppered bottle, when a brown precipitate falls, which is sesquioxide in combination with ammonia. This is dissolved in hydrochloric acid, evaporated to dryness, and exposed to a strong heat; osmium in a pulverized state is left behind. It is a bluish metal, brittle, and infusible.

(516.) OXIDES OF OSMIUM.—These are four: OsO, Os^2O^3, OsO^2, and OsO^4; the last is an acid. It is prepared by heating osmium in a tube through which oxygen is passed; it rises in vapour, and condenses in a cool part of the tube; it is volatile under 42°, of a peculiarly offensive odour, and very poisonous.

There are four chlorides corresponding to the oxides.

CHAPTER VI.

MANIPULATION.

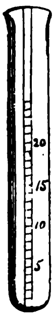
(517.) This term is applied to the method of conducting the different experiments. Those who require full information cannot do better than purchase the work of Professor Faraday on this subject; we propose merely to give a slight sketch of the manner in which a person with small means may set about his experiments at a cheap rate.

(518.) If it be intended seriously to study chemistry, a room should, if possible, be appropriated as a laboratory; it should be furnished with a chimney, which may be with or without a fire-place, and if high enough to stand under so much the better. A sink is also very desirable, and cupboards. If gas be laid on, it will be found very convenient and economical. The room should be dry, light, and airy. It is hardly likely all these advantages can be secured at once. Much may be done, however, with very limited means and accommodation, and the chemical student must act accordingly. A table, furnished with drawers, should be placed in a light part of the room, to serve as a working table: it is best of stout deal, and may have a channel cut round it, in order to collect any valuable product that may be spilt, such as mercury. There should also be shelves to hold the bottles containing the re-agents, which should be carefully labelled.

(519.) **Balance and Weighing.**—It is not to be supposed that those for whom this work is written will be able to afford an expensive balance. The small apothecary's scales in a box are sufficient; they turn, when well made, with about the one-fifth of a grain; the great disadvantage of them is that the weights are the ordinary apothecaries' weights, when they had better consist of 1, 2, 3, 4, 10, 20, 30, 40, 100, 200, 300, 400 grain weights. A common pair of kitchen scales should be used for larger quantities than the small scales will weigh conveniently. The weights should be tested by weighing one against the other. If quantitative analysis be attempted, a good balance is indispensable.

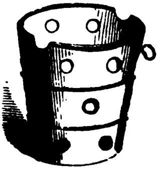
(520.) Liquids are more conveniently measured than weighed; for this purpose graduated measures are sold. They usually hold exactly an ounce of distilled water. They should be graduated on both sides, and the liquid brought up to the marks. Where great accuracy is required the liquid must be weighed; for this purpose the vessel to contain it must be put into one scale and counterpoised with shot, then the weight required in the other scale, and the liquid carefully added, till the required quantity is obtained; a drop or two may be added or taken out by means of a glass tube, drawn to a point, and closed at the other end by the finger.

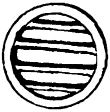
(521.) **Graduated Tubes** can be made without difficulty by weighing into them water or mercury. If the student possess an accurate balance this may be done with advantage. A cubic inch of water at 62° weighs 252.458 grains, and a cubic inch of mercury 3425.35 grains; of course, the accuracy of the divisions in the tube will depend on the care with which the mercury is weighed into it. A hint may be here given to the student of limited means:—it is, only to buy those things which he cannot make himself. It would be better, therefore, to procure a good balance and one or two accurate measures, and make the coarser ones, than to purchase a number of inferior instruments. It is to be observed, with respect to making tubes, that the mercury and the water must be pure, and the tube placed in the same position after each weighing. This may be done by placing it in an angle, formed by nailing an upright board in a light place against a wall. The graduations may be marked on with a scratching diamond, or even a file. Two lines should be drawn parallel on one side, and two exactly opposite on the other, and divisions marked with a file, and then numbered. It is necessary to mark the divisions on both sides of the tube, that no error may exist from having it out of level.

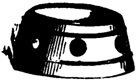


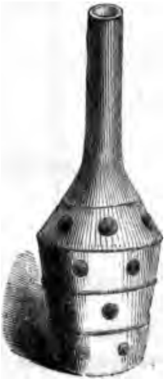
(522.) A specific gravity bottle, as explained in Art. (28), is useful. It is, however, by no means necessary; any bottle not too heavy will do as well. Thus, suppose a bottle contains 320 grains of distilled water and 550 grains of sulphuric acid, what is the specific gravity of the acid? Divide 550 by 320 by the rule for decimal division, and the result is 1.750, the specific gravity required. The bottle should be quite dry when the liquids are introduced, and when filled, and the stopper put in, should be wiped on the outside, and carefully weighed. An ingenious experimenter would easily construct a counterpoise for his bottle out of a piece of clean lead.

(523.) Application of Heat, Furnaces, and Lamp.—An ordinary fireplace is seldom convenient for any chemical operations; it is desirable, therefore, to have other means for producing the necessary heat. A useful furnace may be made out of a large black-lead crucible, or a blue pot, as it is called in the arts. One about twelve inches high and seven inches at the top will make a good furnace, and will cost about six shillings. Holes, as represented in the figure, must be made in the sides, by making a small hole with a gimblet, and then enlarging with a rat's-tail file, and lastly with a round rasp. It should then be bound round with stout iron wire, and two handles of the same made for the convenience of moving it. A little round grate should be dropped in, so as to be just above the bottom row of holes. If another be provided for the top row it will be found convenient. Another piece, also made of blue pot, may be put on when the heat is required to be higher, and a small iron tube placed above this for increasing the draught. Stoppers should be made of soft brick to be put into the holes, in order to check the draught. Charcoal, or a mixture of charcoal and coke, is a good fuel. The





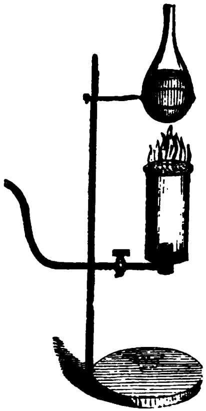




holes in the furnace are convenient for tube operations, and should be therefore made exactly opposite each other.

(524.) A very excellent and powerful furnace might be built of brick, at a small expense. It should then be provided with a sand bath, which is a round or square dish of cast-iron, about two inches deep, filled with sand, and fixed in a convenient place over the fire. A smith's forge is sometimes useful; a very strong heat may be obtained by the same methods as the smith uses, by piling damp coals on the fire, leaving one or two holes for the escape of the blast. By means of a forge a crucible can be rapidly raised to a full white heat.

(525.) Lamps.—The ordinary spirit-lamp will generally be all that is necessary; they are to be bought of all instrument makers. The fuel is pyroxilic spirit or wood naphtha; spirit of wine is more expensive. An oil lamp is also convenient and economical. It should be an Argand;[*] that is, with a circular wick; an ordinary reading-lamp would answer admirably. If gas can be procured much spirit may be saved; it is very economical, and may be burnt at the top of a gauzed chimney, or in an ordinary argand burner. The flame admits of perfect regulation. Vulcanized tube makes the connexions very easily. A movable gas lamp can be procured in London of



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[*] So called from the name of its inventor.

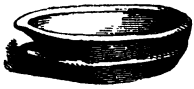
the form represented in the figure. The first expense is considerable, but it soon pays for itself by the great economy in its use.

(526.) BLOW-PIPES.—The mouth blow-pipe is highly convenient. There are many forms of this instrument; that proposed by Dr. Black is made in tin; it is cheap and useful. The appearance of the blow-pipe flame has been already described (63). Many persons are much fatigued by its use; this is because they blow from the lungs, instead of from the mouth. Let any person puff out his cheeks, he will find that it is quite possible to breathe while they remain distended; if he now insert a blow-pipe between his lips, he will find that a strong stream of air is escaping from it. The mouth may be filled without fatigue from the lungs, and the operator then breathe through the nose as usual. A constant blast may be thus maintained for almost any period, without much fatigue.

(527.) Much information may be obtained by observing how substances behave when exposed to the flame of the blow-pipe: the outside of the blue flame oxidates, the inside reduces. A small globule of tin may be used to acquire, by experience, a knowledge of these properties of the flame. In the oxidating part it is converted into an earthy substance, which is the oxide, which again becomes metallic on bringing it into the reducing flame.

(528.) Charcoal forms a convenient support for substances under examination by the blow-pipe. A piece of alder-wood charcoal may have a small hole in it, in which the substance to be examined is lodged; the blast must be directed sideways into it, so as to strike the substance, and be deflect from it over the edge of the other side. It should examined with a magnifying glass. An ordina candle may be used, the wick being kept snuff and a little bent, the blast being directed upwar The table blow-pipe is useful: it is simply a tal furnished with a double bellows, a jet for t blast, and lamp, either oil or gas. The first e pense is considerable; it would be found, howev exceedingly desirable, especially in the count rendering the experimenter independent, to a gr extent, of instrument makers. It might be c structed at a small price, by a clever manipulat The author constructed one for himself, in whi air is blown into the centre of a gas flame; it a swers admirably.

(529.) WATER BATH.—In certain cases it is cessary to expose flasks, &c. to a steady heat, bel a certain temperature; thus, for example, suppos flask is to be kept for some time at a heat just eq to that of boiling water, the object may be attai by heating it through the medium of a water-ba that is, by plunging the flask into a saucepan, other convenient vessel, and putting this on the fi it is manifest that the heat of the contained vessel it be surrounded on all sides by the water, will ne rise above 212°. The flask may be prevented fr touching the bottom of the saucepan by means a little tow, or whisp of straw; the necks sho be put through a hole in a board resting upon top of the saucepan. A large evaporating d put into a smaller, and char with a sufficient quantity water, will answer well for d ing powders, which must



(for fear of decomposition, or other reasons) be exposed to a higher temperature than 212°. If a lower temperature be required, it may be obtained by putting a thermometer in the lower vessel, and taking care that the heat do not rise above the specified temperature. If a heat somewhat above that of boiling water be required, it may be obtained by saturating the water with certain salts, or using a metallic bath; thus, a saturated solution of—

	Deg.
Bitartrate of Potash boils at	214
Alum	220
Borax	222
Common Salt	224
Tartrate of Potash	234
Muriate of Ammonia	236
Nitre	238
Tin melts	441
Lead melts	609

And so on. Hot-air and steam may also be used with advantage. A warm draught of dry air, where admissible, is very effective as a drying agent.

(530.) TRITURATION.—This is the term used for grinding dry substances to powder. It is merely necessary for this purpose that the mortar be not too smooth; it should, however, be hard and strong, especially where hard substances are to be reduced to powder. Care must be taken not to use so much force as to endanger the mortar, nor is it advisable to have in any case a very large quantity of material in it. A mixture of pounding and grinding is usually most advantageous, and, in a word, a golden rule is—be patient and not too violent.

(531.) Many metals are comminuted by filing.

This is always laborious and tedious, besides which the steel of the file contaminates the other metal. In some cases granulation may be resorted to, that is, pouring the melted metal from a considerable height, 2 or 3 feet, into water. Powders often have a tendency to get damp, a circumstance which requires attention, particularly in analytical chemistry.

(532.) SOLUTION is the term used to express the dissolving of a solid substance in a fluid. When not otherwise stated, water is understood as the fluid employed. Inasmuch as the bulk of the solvent is usually not much altered, its specific gravity is increased; thus, solution of salt and water is heavier than an equal bulk of water alone, and the quantity of salt dissolved may be ascertained by means of the specific gravity of the fluid. Generally, salts and other substances are more soluble in hot water than in cold; hence, when saturated solutions are required, the advantage of using boiling water. Substances in fine powder dissolve more readily than when in large pieces.

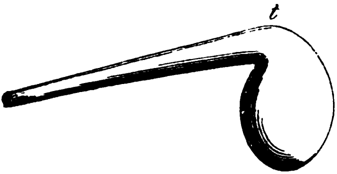
(533.) Solutions are made in basins, glasses, and flasks, according to circumstances. Stirrers are required; they should be made of glass rods, and not of tubes, as the former retain dirt in the bores. Stirring facilitates solution. If stirrers be very slightly bent they will then not roll off tables. By putting the lips of the flasks, basins, &c. to the stirrer, the solutions may be poured from vessel to vessel without spilling a drop. In analytical operations, the stirrers, flasks, &c. must all be carefully washed and the washings returned to the solution, that nothing may be lost.

(534.) LIXIVIATION is used when soluble substances are to be dissolved out from porous but insoluble matter, as when iodine salts are to be dissolved away from charcoal, &c. resulting from burnt sea-weed. This is best done in a funnel. A cork is put into its bottom, then two or three larger pieces of ash may be first put in, and smaller portions over it; water is then poured in sufficient to cover the ash; in a little while it will form a saturated solution in the lower part of the funnel; the cork is withdrawn, and fresh water added, till the ashes are exhausted.

When the body is slowly soluble, and has to be kept in contact with the fluid a long time, the process is called *digestion.*

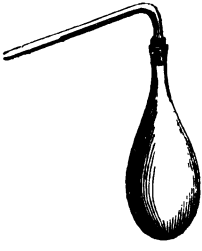
(535.) DISTILLATION. SUBLIMATION.—When a body is converted into a vapour which condenses by cold into a liquid, the process of conversion and condensation is called distillation; if into a solid, sublimation. The form of apparatus requisite for distilling water has already been given in section (26). As distilled water is essential to almost every chemical experiment, a means of supplying it must be at hand. A large tea-kettle, a few feet of clean tin gas tube, and a pail, will generally make a sufficiently good still. The water which surrounds the worm must be kept perfectly cool, or at least only just warm at the top, and the still-worm as free from obstruction as possible. In London, distilled water may be purchased.

(536.) Distillations on the small scale are performed in retorts and flasks. The form of a retort is represented on the following page. They should always be thin, especially at the bottom, where exposed to heat. They are made of glass,



porcelain, earthenware, and metal. Some of them have a stopper at *t;* they are then said to be tubulated. The retort may be heated by a lamp, or on the sand-bath. Plain retorts are filled by means of a long-necked funnel.

(537.) Of all useful vessels, flasks are the most so to the chemist of limited means; they may be purchased at a shilling a dozen from the oil-shops; they are made of a hard green glass, and are usually thin at the bottom; easily cleaned and charged, and if broken, no great harm is done. The film of oil which adheres is removed with concentrated hot sulphuric acid; this should be poured in and worked round and round in the flask with sand. If common soda and lime be afterwards boiled together in it, it will be quite cleaned; this is seldom necessary. Flasks may be rendered available as retorts by means of a bent tube and perforated cork. A set of cork borers, capable of making holes of different sizes, may be very advantageously purchased; and the tube may be bent over a spirit-lamp, as will be hereafter explained (561). Another flask may be used as a receiver, and may be kept cool by surrounding it with a wet rag; or if ice is procurable, by putting it in a basin and surrounding it with ice. One or two



retorts will be desirable, but the student should use them cautiously, and seldom, in consequence of their comparatively high price.

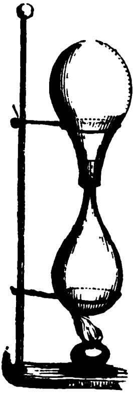
(538.) If the tube from the flask or the neck of the retort be kept cool, which may be done by wrapping wet paper or rag round them, the liquid will run in drops from the end of the tube; this is highly convenient if it be desirable frequently to examine the distillate.

A Liebig's condenser, which is made of a tin tube stopped at both ends with perforated corks, through the centre of which a glass tube passes, is very convenient; there is a pipe through which a stream of cold water runs, keeping the glass tube always cool.

(539.) When the corks do not fit tight into the flasks, they are often made so by anointing them with a paste made of pipeclay and water; this is effectual even with chlorine.

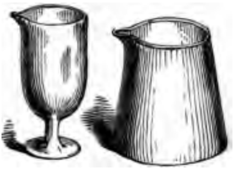
(540.) Caoutchouc joints are very good. India rubber is now sold in sheets, of which tubes may be made by wrapping round a tube, cutting off the superfluous caoutchouc with a pair of clean scissors, and, putting the edges together, they unite and form a very good tube; if this is slipped on to any glass tubes, and tied with string, it makes a very tight and flexible junction. Vulcanized India rubber tubing is also very useful, its elasticity being very great; it costs about one shilling per foot and upwards, according to its size.

(541.) An iron retort (which may be made out of a piece of gas tube, the end of which has been welded up) is highly useful in the distillation of certain metals, and for other purposes. If, as will be the case with most of the students who read this treatise, their experiments be directed to practical chemistry as applied to the arts, the possibility of an iron retort being used or not may make all the difference as to whether the process be commercially a good one; for though the iron of the retort will, in many processes, be acted on, it may, nevertheless, be sometimes desirable to submit to this inconvenience, in exchange for the very great facility with which that metal is worked, and its comparative cheapness. When iron will not answer, earthenware or porcelain must be used. No doubt an ink bottle carefully heated might be used as a cheap substitute for a porcelain retort in many operations. Of course glass will always be used for temperatures below redness; and green glass, coated with Stourbridge clay, may be used up to a low red heat.



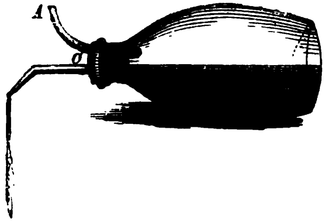
(542.) The arrangements for sublimation resemble those for distillation. Often the neck of one flask may be put into the neck of another one somewhat wider, and the upper flask kept cool by a piece of moistened paper. In case of difficulty in removing the sublimate, a cracked glass might be used and broken when the operation is over; or a bell-jar inverted, and covered at the top with a plate of glass.

(543.) PRECIPITATION has often to be performed in analytical chemistry. In many cases where an excess of the precipitant is of no consequence, a little more than is required may be used, and the liquid put aside to settle. When, however, the exact quantity must be used, then less than is required must be added, and the liquid allowed to settle, and, when clear enough, a drop or two of the precipitant added; if this produces a considerable effect more must be added; if not, the precipitant must be added drop by drop till it ceases to produce any effect. If the precipitate is one which subsides slowly, a drop or two may be taken from the surface and transferred to a glass plate, and then a drop of the precipitant; the quantity required may be judged from the effect produced. Care must be taken to mix well by stirring. The vessels to be used are figured in the margin; the advantage of the one with the bottom larger than the top, is, that the precipitate does not hang to the sides.

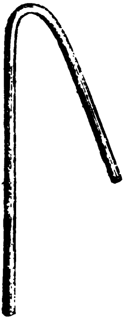


(544.) FILTERING.—Precipitates are often conveniently separated from the solution by filtering. White blotting paper is generally used for this purpose, and is convenient; flannel and linen are sometimes used in rough operations.

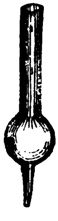
The filtering paper should be cut into squares, which are then folded in four, corner to corner; one side is opened, forming a sort of cone; it is supported in a funnel. It is convenient to have a filtering stand, which is simply a board with holes in it to put the funnels through, and standing on legs high enough to admit the vessels underneath. It should be borne in mind that these vessels should always be capable of containing the whole contents of the filter; neglect of this will occasion an infinity of trouble with slops and waste. Precipitates usually require washing. A washing bottle is useful, and is easily constructed; the figure will show how this is done. The tube A is blown into, and the water runs out in a stream at B; C is a cork. The stream is useful for washing the precipitate from the sides of the filter into the bottom.



(545.) Decantation is another method, and often a preferable one, of accomplishing the same thing. In this case the precipitate is allowed to settle, and the liquid poured off by a steady hand; or, still better, a syphon, which is a bent tube of glass, may be used; this is filled with liquid, and then the longer leg being stopped with the finger, the shorter is put into the liquid and the finger removed, when the contents run quickly out. In this way the supernatant fluid may be drawn off until it begins to run thick.



(546.) The Pipette is a useful instrument for drawing off small quantities of fluid for examination or otherwise. It is made of a tube of glass with a bulb, as in the figure. The liquid is drawn up by the breath into the bulb, or by immersing it below that level into the fluid. It is then stopped with the finger at the top, and the liquid may thus safely be transferred.



(547.) Crystallization is performed in evaporating basins, and several of different sizes should be provided. If the crystals are required large, the liquid must be evaporated slowly; if not, the liquid may be boiled down to dryness. Care must be taken in this case to stir well, especially towards the close of the process, otherwise the confined steam is liable to scatter the crystals as it bursts from the nearly solid mass. Caution, too, is often required that the heat do not rise too high at the close of the operation. A very good plan is, when the work of the day is over, to put the dish in the sand-bath, fill up the sand round it, and leave it till the morning; the heat falls very slowly, and thus a crop of good crystals is formed. Solutions do not begin to crystallize till the liquid is saturated. The liquid may be known to be saturated when a drop of the solution put on a glass plate shoots into crystals. Crystallization may be often used with advantage to separate salts; isomorphous salts, however, can often not be separated in this way: for example, sulphate of iron and copper crystallize together from a mixed solution. Evaporating basins are usually made of earthenware, glazed on the inside. A useful metal basin may be made by hammering up the edge of a piece of round sheet-lead, and is highly convenient for rough operations.

(548.) Desiccation, Drying. — The facility with which this operation is performed, depends on the nature of the substance; if heat must not be applied, and an air-pump is not at hand, the substance to be dried may be put under a bell-glass, and a dish containing sulphuric acid, or chloride of calcium, or some other substance which has a considerable affinity for water. When heat may be applied, drying is easy. A cold current of dry air is more efficacious than a hot, still atmosphere. If an air-pump can be procured, many substances which will not bear to be heated may be dried by exhausting the air from the bell-glass above-mentioned.

(549.) COLOURED TESTS. LITMUS PAPER.—Good litmus is to be rubbed to powder with hot water in a mortar, transferred to a flask with warm water in the proportion of an ounce of litmus to a pint of water. It is to be covered up for an hour, when the warm, clear, blue liquid may be poured off. The paper, which should be good filtering paper, free from lime, is to be dipped into this. It should be dried out of contact of all acid fumes, and kept in the dark. The blue in the flask is not exhausted, but the liquids from it will have to be evaporated to the proper strength.

TURMERIC PAPER is made in the same way. One ounce of the root is boiled with twelve of water, strained through a cloth, and allowed to settle; the paper is then dipped in. These papers should be cut into strips, and may be put into a wide-mouth, stoppered bottle, covered with paper, to exclude the light. The blue of litmus is reddened by an acid, and the yellow of turmeric browned by an alkali. It is to be remembered, however, that boracic acid browns turmeric paper; so do salts of iron, tin, and uranium. Ammonia will not redden turmeric unless it be damp; nor will a perfectly dry acid gas redden perfectly dry litmus.

LEAD PAPER is made by dipping filtering paper into a solution of subacetate of lead; it is instantly blackened by the least breath of sulphuretted hydrogen.

(550.) MANAGEMENT OF GASES.—Gases, when not soluble in water, are collected by means of that fluid. The pneumatic trough is very conveniently made from a small flat-bottomed foot-bath. It must be fitted with a shelf made of either wood or metal, with one or more holes in it, which should be placed at about two to three inches below the top of the tub. If the student can obtain a sight of a pneumatic trough, he will not have the slightest difficulty in constructing one for himself.

(551.) Jars for the reception of gases are either plain, stoppered, or capped and stop-cocked. One or two jars are required, which are graduated; they should be capped and stop-cocked, but should not be used generally, as they are expensive. Glass saucers are sold with them; soup-plates will do quite as well, and are cheaper. Gases may be transferred from jar to jar by filling that to which the gas is to be transferred with water, and standing on the edge of the shelf, just projecting over it; the jar of gas is sunk, mouth downwards, underneath the edge of the other, and then, by gradually inclining it, the gas may be quietly conducted up in bubbles. When gas is to be transferred from a very large to a very small jar, it should be done by means of a funnel. The mercurial trough is a very expensive instrument, and the opacity of the fluid, and its great weight, make the manipulation difficult. It is hardly likely, however, to be in the hands of a student whose means are limited.

(552.) MEASURING GASES.—The jar should be filled with water, and the gas passed up into it till it is nearly at the division indicated; the jar is then to be pressed down in the water till the fluid inside and outside are at the same level; the quantity to be introduced can then be judged of, which must be cautiously done, bubble by bubble. Bring the liquid inside the jar to a level; if a little too much have been introduced, it may be allowed to escape when the jar is brought down in the liquid to the level of the division, by cautiously opening the stop-cock. It is seldom, however, that those for whom this treatise is intended will require anything like an exact determination of the quantity of a gas.

(553.) CRUCIBLE OPERATIONS.—Crucibles were so called from originally being impressed with the sign of the cross by the alchemists. This name is now given to all open vessels intended to bear high temperatures. They are of various kinds—English, Hessian, Cornish, and black lead. The three last are by far the best. Those of black lead contain iron and charcoal, and are therefore liable to contaminate the substances fused in them; they bear a high heat, however, and do not crack. Fluxes, such as carbonate of soda, act on earthen crucibles at a high temperature, particularly English. For the more delicate investigations porcelain crucibles are employed.

(554.) Very constantly a covered crucible is directed to be used. Covers are sold with them, and sometimes require to be luted on. This is done with Stourbridge clay. A soft smooth paste is made by pounding it with water; and with this the covers are cemented on. The crucible must be put into a warm place to dry, and the more slowly the better.

(555.) *Platinum Crucibles* are very useful, but exceedingly expensive; the price of manufactured platinum being from 32*s.* to 38*s.* per ounce. If the student be so fortunate as to possess one, let him only use it in cases of necessity.

(556.) FLUXES are necessary in some cases of metallic reductions; they dissolve impurities, protect the metal from the air, and sometimes exert a reducing agency.

(557.) BLACK FLUX is made by adding, in small portions, to a dull red-hot crucible, 2 parts tartar and 1 nitre; it consists of finely divided charcoal and carbonate of potash.

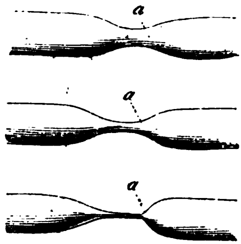
(558.) WHITE FLUX is a carbonate of potash made by using equal parts of nitre and tartar, and heating as above.

Borax and carbonate of soda are useful fluxes.

(559.) GLASS TUBING, BENDING, BLOWING, &c. —The uses to which glass tubing can be applied are very various, and in the hands of a clever experimenter may be used in a number of ways, so as entirely to supersede the necessity for more costly apparatus. An experiment tried in a tube is often just as valuable as though a ton of matter were used.

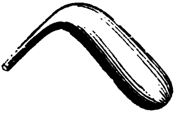
(560.) The best apparatus is the table blow-pipe; the lamp should be so trimmed as to give a steady flame when urged by the blast. In the absence of the table blow-pipe, the mouth blow-pipe, or even the flame of a spirit-lamp, may be used with advantage. The glass must be warmed slowly, especially when thick, or it is liable to crack, and particularly if heated near an edge; it should, therefore, be advanced gradually into the flame. If soot is deposited on the glass it will cause a stain, by the reduction of the lead contained in all *flint* glass; this should, therefore, be avoided.

(561.) Bending a Tube.—For this purpose the tube must be gradually advanced into the flame and heated all round, till it begins to bend in the hands. It must not then be bent suddenly, or the bend will be wrinkled on the inside, very thin on the outside, and the bore diminished; but it must be bent *slowly*, and the glass advanced *gradually* forward in the flame, so that the bend may be even and well rounded; if this be not attended to the tube will probably fly in pieces when cold. The glass may be annealed by putting it on the hottest part of the sand bath, and gradually drawing it away to the cold part, or else taking it very slowly out of the flame. If the glass be cooled too rapidly, when thick it is almost certain to fly. Tubes may be closed by drawing them out when hot; the heat must be directed nearer to the tube to be closed. The figure shows the operation in its various stages; the part where the greatest heat is directed being denoted by the lines *a a a*. A little knob of glass is left; this may, if small, be got rid of by heating the tube and blowing gently into it.



(562.) Blowing bulbs and making expansions are difficult operations. The glass must be equally heated, and as much as may be of the same thickness, the thickest parts being made hottest. The air must be sent in from the mouth, and caution is necessary, or else the bulb will suddenly expand in one place and the experiment will fail; patience, practice, and perseverance are the words to be impressed on the operator's mind; if, however, the student can succeed, he may make a vast variety of small apparatus, such as retorts, receivers, &c.

1.



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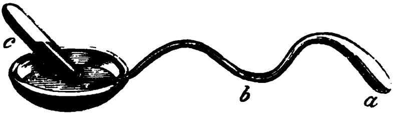

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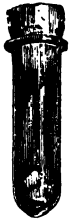

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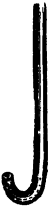

1, 2, 3 are forms recommended by Dr. Faraday; 1 is an ordinary retort; 2 a retort for distilling a fluid where a gas is expected; *a* is the point where heat is applied; the liquid condenses in *b*, and the gas passes on and is collected in a test tube. 3 is a bottle for holding a specimen. 4 is a mercurial receiver, which only requires mercury sufficient to fill it; a *little* of that metal is *necessary* to the chemist.

(563.) Glass tubing is cut with a file; a triangular file is used for this purpose, and a scratch made all round the tube; it is then broken with a motion of the hands between pulling and bending. Files may also be used for marking on glass. When a glass vessel is broken the fragments should not be thrown hastily away, as very often they may be made available. The feet of broken glasses will do for covers; evaporating glasses may be made out of broken Florence flasks. If a portion of a flask, &c. be put on a red-hot ring, a crack will almost always be formed in the direction of the ring. In the same way, a crack that has commenced may be led in any required direction by drawing a red-hot iron along the glass from the beginning of the crack; with the help of the file and hot iron, many a useful vessel may thus be made: if there be no crack, it may be commenced by putting the iron at the place required, or a little above it, and then touching the glass with the moist finger; this will certainly originate a crack, which may be led by the hot iron in any required direction.

(564.) When a glass tube is not at hand, paper may often be made to supply its place. Rolled paper tubes, made out of good writing-paper, are air-tight at low pressures. Waxed paper is made by laying it on a hot plate, and rubbing it over with wax in a muslin bag. Funnels, tubes, dishes, &c., may be made out of it, through which even acid liquids may be passed.

(565.) Tube Operations.—Very often gas or vapour is directed to be passed over a substance heated in a tube. The tube for this purpose is set across a furnace, and the gas passed through it;

the material used for the tube depends on the nature of the operation and the heat.

(566.) Iron tubes are most useful, and may be used with great advantage when not acted on by the substances experimented with. Iron gas-tube is very useful, and may be procured of various sizes.

(567.) Berlin, wedgwood, and common earthenware are used. The first has this advantage, that it is not very liable to fly, which the others are; it is, however, the most expensive. Glass is the most useful of all; and a hard infusible German glass is now sold which is excellent.

(568.) A tube furnace is now sold in London. It is a long trough of wrought-iron, with numerous supports for the tube, and one end movable. It is useful enough, especially in organic analysis. A furnace may be constructed extemporaneously, by putting bricks long-ways upon an iron grating. The tube, if of glass, must be supported, which may be done in a variety of ways; such, for example, as putting it inside an iron tube, or supporting it at intervals by cross pieces of brick; corks or caoutchouc joints may be used. Charcoal is the best fuel.

(569.) Lutes are soft, adhesive mixtures, intended for stopping the joints, and uniting together different portions of apparatus.

(570.) Stourbridge clay is very useful, as it stands a very high temperature without fusing. It may be made into a paste with water. It may also be used as a coating for earthen retorts, which should be from a quarter to half an inch thick.

(571.) Windsor loam may be used for the same purpose. It is cheaper, but will not stand so high a heat.

(572.) Glazier's putty is a useful lute to prevent the escape of corrosive vapours. It is made by pounding together pipeclay and linseed-oil. Paper pasted over a joint will often render it sufficiently tight.

(573.) Cap cement is used to unite glass to brass, as in the electrical machine, or the capped air-jar. It is composed of resin five parts, yellow bees'-wax one, and a little Venetian red in fine powder; it should be heated up to 212°, and stirred well, the red being added gradually till the mixture ceases to froth; it is then to be cooled, stirring continually till the mixture becomes too thick to settle. The cap and glass must both be warm when it is to be applied.

(574.) Soft cement is made by melting equal weights of turpentine and yellow wax, with Venetian red enough to colour it. It is as soft as soap when cold.

(575.) Cleanliness and Washing. — The student should keep all his things clean, more especially if he proposes to himself anything like analysis. Sand or paper will often assist in cleaning the inside of bottles, flasks, &c. Generally, as the student will know what a vessel has been dirtied with, he will find no difficulty in determining what reagent should be used to clean it. For example, the author was once experimenting with the crude napthaline of the gas-works; water and sulphuric acid would not remove it from the flask, but a little pyroxilic spirit was immediately effectual. The bottles, flasks, &c. should be always well washed in common water, rinsed out once or twice, and lastly rinsed with distilled water.

(576.) Mercury is often contaminated with base metals, such as lead and tin: weak nitric acid, or, still better, acid nitrate of mercury, will dissolve out the baser metals, leaving the mercury. That which has been used for this purpose should be kept apart from the pure nitrate, which will be required as a reagent.

(577.) The stoppers of bottles are liable to become fixed; they may often be removed by tapping them gently, first on one side and then on the other, with a piece of wood. A little olive oil may be put on the stopper, and the neck then gently but rapidly heated. If the substance in the bottle be a saline solution, and the crystallization have set the stopper, water, or a fluid which is known to be a solvent of the crystals, may be used. Heat, oil, and tapping will remove very obstinate stoppers.

(578.) MISCELLANEOUS HINTS AND RULES.—The student, if he intends to study chemistry seriously, or perform any experiments of research, should keep a note-book, in which all his experiments should be entered:—the appearance of liquid solutions, behaviour of substances under examination, the success or failure of the experiment; and these should be noted at the time.

(579.) He should waste nothing, nor throw away anything which is likely to be of any value. In making his purchases he should always carefully consider what he wants to do, and purchase accordingly. The prices of the operative chemists are high, though, considering the comparatively limited demand for their goods, by no means extravagantly so. They are, too, generally quite willing to give the student any information, or show him any new and useful apparatus; and he will do well to deal with those who will afford him willingly so great an advantage. If he find he have not the means at hand of trying an experiment, he should consider whether he may not by a little ingenuity supply them. He should endeavour to form habits of order, cleanliness, patience, perseverance, and observation; these will always be useful. Nor should he allow economy to be an excuse for inaccuracy or untidiness. Above all, let the student recollect that the piety of the old alchemists gave the name to the crucible; and though in many respects their religion and their science were erroneous, they must have been, in both respects, far superior to the chemist who cannot still trace the cross upon the crucible.

APPENDIX.

I. ENGLISH WEIGHTS AND MEASURES.

THE natural standard to which all our measures are referred, depends on the time of the earth's rotation, and the amount of gravitation at a given point of its surface; both which elements have been proved by astronomy to be invariable. The time of the earth's rotation is subdivided alike in all civilized countries, into 86,400 seconds. It has, therefore, been made a law in this country, that the distance from the point of suspension to the centre of oscillation, of a pendulum which, when placed in vacuo, in the latitude of London, and at the level of the sea, makes 86,400 vibrations in a mean solar day, shall be taken as 39.1393 English inches. Accordingly, the platinum yard scale adopted for a national standard, measures at the temperature of 62° Fahr., 36 such inches.

WEIGHTS.

Weights are connected with the above standard, by the enactments that 277.274 cubic inches shall constitute an *Imperial Gallon;* and that the weight of this volume of pure water, weighed in air of 30 inches pressure, at 62°, shall be taken as 10 *avoirdupois pounds*, or 70,000 *grains.*

The two systems of weights called *Troy* and *Avoirdupois*, have no common integer except the *grain.* Though the names *pound, ounce*, and *drachm* are common to both systems, they denote different quantities in each.

The English *troy* pound is subdivided into twelve ounces, and each ounce is equal to 480 grains. The subdivisions of the troy ounce, called *Apothecaries' weight*, are into 8 drachms, each drachm into 3 scruples, and each scruple into 20 grains. The troy ounce is also sometimes divided into 20 pennyweights, of 24 grains each. These are the weights generally employed; but for philosophical purposes, ambiguity is most easily avoided, by employing the *grain* as integer: and the Laboratory should be provided with good sets of weights, from 1,000 grains downwards; the grain should be decimally subdivided into tenths, hundredths, and thousandths.

The standard of most articles bought and sold in common life, is the *avoirdupois pound*, which is equal to 7,000 grains, and is divided into 16 ounces, of 437.5 grains each. The avoirdupois ounce is legally divided into 16 drachms, of 27.34375 grains each; but this division is rejected in all ordinary cases, in consequence of the confusion likely to result between the troy and avoirdupois drachm, so that the term *drachm* is almost exclusively employed to denote the *eighth part of a troy ounce*, or 60 grains.

In the following Tables are shown the subdivisions of the English troy and avoirdupois pounds, and their correspondence with the French *gramme*.

TROY WEIGHT.

Pound.		Ounces.		Drms.		Scruples.		Grains.		Grammes.
1	=	12	=	96	=	288	=	5760	=	about 372.96
		1	=	8	=	24	=	480	=	31.08
				1	=	3	=	60	=	3.885
						1	=	20	=	1.295
								1	=	0.06475

AVOIRDUPOIS WEIGHT.

Pound.		Ounces.		Drms.		Grains.		Grammes.
1	=	16	=	256	=	7000	=	about 453.25
		1	=	16	=	437.5	=	28.328
				1	=	27.34375	=	1.7705

The larger units of this system are multiples of the pound by 7, thus—

Ton.		Hundredweights.		Quarters.		Stone.		Cloves.		Pounds.
1	=	20	=	80	=	160	=	320	=	2240
		1	=	4	=	8	=	16	=	112
				1	=	2	=	4	=	28
						1	=	2	=	14
								1	=	7

MEASURES OF VOLUME.

Previous to the introduction of the present *Imperial Measure*, as it is termed, *Wine Measure* was generally used for measures of capacity: the *wine pint* corresponds to 28.875 cubical inches of water, at the temperature of 60°. It was subdivided into 16 ounces; the ounce into 8 drachms. Two pints being = a quart, and 4 quarts = 1 gallon.

The old *ale pint* contained 35.25 cubical inches of water, at 60°.

For chemical use, the most convenient *measure* is the bulk occupied by the troy ounce of distilled water, which may be subdivided into 480 grains, and which is equal to 1.8047 cubical inches.

The Imperial Gallon, now substituted for all other measures of volume, is one-fifth more than the old wine gallon (30 Imperial = 36 Wine), and one-sixtieth less than the old ale gallon (30.5 Imperial = 30 Ale). It contains 10 avoirdupois pounds of water, of 7,000 grains each = 70,000 grains = 277.274 cubic inches of water, at 62°: the weight of the cubic inch of water, at 62°, being 252.458 grains. The Imperial Pint is = one-eighth of the gallon, = 8,750 grains, = 34.66 cubic inches.

1,728 cubic inches = 1 cubic foot.

46,656 cubic inches = 27 cubic feet = 1 cubic yard.

1 *bushel* (Imperial) contains 2,218.19 cubic inches; and 1 *barrel*, 9,981.864 cubic inches.

MEASURES OF LENGTH AND SURFACE.

The *inch* is the smallest lineal integer now used. For mechanical purposes it is divided either duodecimally or by continual bisection; but for scientific purposes it is most convenient to divide it decimally. The larger units are thus related to it.

Mile.	Furlongs.	Chains.	Rods.	Fathoms.	Yards.	Feet.	Links.	Inches.
1	=8	=80	=320	=880	=1760	=5280	=8000	=63360
	1	=10	= 40	=110	= 220	= 660	=1000	= 7920
		1	= 4	= 11	= 22	= 66	= 100	= 792
			1	= 2.75	= 5.5	= 16.5	= 25	= 198
				1	= 2	= 6	= $9\frac{1}{11}$	= 72
					1	= 3	= $4\frac{6}{11}$	= 36
						1	= $1\frac{17}{88}$	= 12
.000125=	.001=	.01=	.04=	.11=	.22=	0.66=	1	= 7.92

It appears, from the above table, that the *link*, which was invented by Gunter, is expressible in exact decimals of each of the other units, notwithstanding their complex relations. It is difficult to conceive how so large a prime number as 11 could find its way into an artificial system; and its great inconvenience has led, in surveying, to the substitution of the chain and link (simple decimal parts of the furlong,) for the smaller integers in common use.

The English measures of length have been adopted by Russia and Denmark, so that they are now used over the greater part of the world.

The mile, furlong, chain, and link, are applied only to horizontal measures; the fathom is used only for vertical measures, for which also, in levelling, the foot is made the sole unit, and is divided decimally instead of duodecimally. The rod, pole, or perch, is not much used as a lineal measure, but its square is a common superficial measure.

All the units of surface are the squares whose sides = the above units of length, except the three following, which have no corresponding lineal units.

The *rood* = 40 perches = 2.5 square chains = 1,210 square yards.

The *acre* = 4 roods = 10 square chains = 4,840 square yards.

The *hide* = 100 acres = 1,000 square chains = 10 square furlongs.

These superficial measures are used only for land, but the *rod* or *perch* is applied also to walls, while the internal surfaces of buildings are reduced to the *square yard*, and their roofs to an unit called a *square*, consisting of 100 square feet.

For scientific purposes the *square inch* is the most convenient unit of surface. Engineers sometimes use also the *circular inch* = .7854 &c. of a square inch.

II. FRENCH WEIGHTS AND MEASURES.

The French metrical system is founded on a single standard of length called a *mètre*, and which is equivalent to the ten-millionth part of the arc of the meridian, extending from the equator to the pole. The length of the mètre, as ascertained by Captain Kater (*Phil. Trans.* 1818), is 39.370788 English inches.

The French measures increase and decrease in decimal proportions, a distinctive prefix being put to the term by which the integer is called. These prefixes are *deca*, *hecto*, *kilo*, and *myria*, taken from the Greek numerals, to express the *multiplication* of the integer by 10, 100, 1,000, and 10,000 respectively: and *deci*, *centi*, and *milli*, from the Latin numerals, to express the *division* of the integer by 10, 100, or 1,000: as in the following table:—

	Mètres.		Mètre.
1 Myriamètre =	10000	1 Mètre =	1.
1 Kilomètre =	1000	1 Decimètre =	0.1
1 Hectomètre =	100	1 Centimètre =	0.01
1 Decamètre =	10	1 Millimètre =	0.001

The kilomètre is the general road measure, and is equal to a mean centesimal minute of the earth's polar circumference. It differs very little from 5 furlongs, English measure.

The *mètre* is the integer of the *measure of length*, and from it all measures of surface, capacity, and weight, are deduced as follows:—

For *superficial dimensions*, the mètre, or its parts squared, are employed. When used for measuring land, the term *are* is adopted, which is a decamètre squared, or very nearly 4 perches; so that an *hectare*, or 100 *ares*, is about equal to 2.5 English acres.

For the integer of the *measure of capacity*, the cubed decimètre is employed, under the name of *litre*, which is about equal to 2$\frac{1}{8}$ English wine pints. But for cheap materials, such as firewood, another unit of volume, 1,000 times greater than the litre, or equal to a cubic mètre, is used, under the name of *stère*, and its multiple and submultiple by 10 constitute a *decastère* and *decistère*.

For the integer of the *measure of weight*, the weight of a cubic centimètre of distilled water, at its maximum density (4.1° Cent.), weighed *in vacuo*, has been adopted: it is called a *gramme*, and is equal to 15.434 English grains. This unit, however, is obviously too small for the purposes of common life; in which, therefore, its multiple by 1,000, or the *kilogramme*, has become the general integer. This weight of pure water occupies exactly a *litre*, or cubic decimètre, thus placing the means of verifying the weights within the reach of every one. The half kilogramme retains the name of the *livre*, though somewhat exceeding the old pound, both of France and England; but, owing to this excess, the *millier*, or 1,000 kilogrammes, may be taken for all common purposes as = an English *ton*, and *quintal* or 50 kilogrammes = 1 *cwt.*, a coincidence ea remembered.

The following are the principal tables of Fre Weights and Measures, which will be found useful in Laboratory:—

MEASURES OF LENGTH.

		English Inches.
Millimètre	=	.03937
Centimètre	=	.39371
Decimètre	=	3.93708
Mètre	=	39.37079
Decamètre	=	393.70788
Hectomètre	=	3937.0788
Kilomètre	=	39370.788
Myriamètre	=	393707.88

MEASURES OF VOLUME.

		Cubic Inches.
Millilitre	=	.06103
Centilitre	=	.61028
Decilitre	=	6.1028
Litre	=	61.028
Decalitre	=	610.28
Hectolitre, or decistère	=	6102.8
Kilolitre, or stère	=	61028.
Mirialitre, or decastère	=	610280.

MEASURES OF WEIGHT.

		English Grains.
Milligramme	=	.0154
Centigramme	=	.1543
Decigramme	=	1.5434
Gramme	=	15.434
Decagramme	=	154.34
Hectogramme	=	1543.4
Kilogramme	=	15434.
Myriagramme	=	154340.

The *kilogramme* is = 2.68098 pounds troy; or 2.20 pounds avoirdupois.

The *coins*, also, are made to bear simple relations b to these weights and to the measures; for the *franc* wei 5 grammes; the *five-franc* piece, 25 grammes; and diameter = 37 millimètres, so that 27 of them, side side, measure a mètre; 37 × 27 = 999.

WITH RE-AGENTS.

IYDRO-PHURET.	FERROCYANIDE OF POTASSIUM.	REMARKS.
oloured . .	White	Amethyst bead, in blowpipe, with borax.
. . . . . .	White, to deep-blue.	
Sp. . . .	Prussian-blue.	
. . . . . .	Greenish white.	
. . . . . .	Greyish green. . .	Blue bead, in blowpipe, with borax.
. . . . . .	White.	
sulphuret. black . . .	White	White precipitate, on adding water to nitrate. Rapidly blackened by sulphuretted hydrogen.
. . . . . .	Reddish brown.	
. . . . . .	Fine red brown.	
. . . . . . hydrate of	White	White precipitate, with sulphuric acid. Insoluble in nitric acid. Yellow with chromate of potash.
. . . . . .	White to yellow.	
S. . . .	Yellow	Purple of Cassius, with chloride of gold.

ed, S, from which it is again precipitated by an acid.

recipitant.

[To face p. 25.

GENERAL CHARACTERS OF SALTS.

DIVISION I.—BASES.

CLASS I.—*The general character of this class is that the bases are not precipitated with Caustic or Carbonated Alkalies, or with Sulphuretted Hydrogen under any circumstances.*

Bases.	*Bichloride of Platinum.*	*Tartaric Acid.*	*Antimoniate of Potash.*	*Remarks.*
POTASH	Yellow, granular, and heavy.	White, granular	None	In testing for potash, the absence of ammonia must be proved, which may be done by exposing the substance to be examined to a red heat.
AMMONIA	Yellow, granular, and heavy.	White, granular	None	Ammonia is given off on heating with lime or potash ley, and is recognised by its odour, and forming a white cloud with hydrochloric acid.
SODA............	None	None	White, granular	The absence of heavy metals and alkaline earths must be ensured, in using antimoniate of potash.

CLASS II.—*A precipitate with Carbonated Alkalies, but none with Sulphuretted Hydrogen under any circumstances.*

Bases.	*Sulphuric Acid.*	*Phosphate of Soda.*	*Oxalic Acid.*		*Hydro-fluo-silicic Acid.*	*Remarks.*
BARYTA	White	White	White	Developed by adding ammonia.	White	Sulphate of baryta is quite insoluble.
STRONTIA	White	White	White		None	Sulphate of strontia is not *quite* insoluble, and precipitates more slowly than sulphate of baryta.
LIME	White in concentrated solutions.	White	White		None	Oxalate of ammonia is the most characteristic test.
MAGNESIA ...	None	White, increased by add. ammonia.	None		None	The most characteristic test is with phosphate of soda and ammonia.

Class III.—*Hydrosulphuret of Ammonia precipitates Hydrated Oxide.*

Bases.	*Potash.*	*Ammonia.*	*Remarks.*
Alumina	White, soluble in excess	White, difficultly soluble in excess.	The only difficulty in detecting alumina is when oxide of chrome is also present, in which case oxide of chrome may be converted into chromic acid by fusion with nitre.
Chrome.......	Bluish green, soluble in excess.	Bluish, slightly soluble in excess.	

Class IV.—*None, or an imperfect precipitate in Acid or Neutral Solutions with Sulphuretted Hydrogen.*

Bases.	*Potash.*	*Sulphuretted Hydrogen.*	*Hydrosulphuret of Ammonia.*	*Remarks.*
Zinc	White yellow, soluble in excess.	Imperfect precipitate in all but alkaline solutions. None at all in acids.	White	Oxide of zinc is the only oxide of this class which is soluble in potash, but it differs from alumina and oxide of chrome, as it is reprecipitated by sulphuretted hydrogen.
Manganese Protoxide	White, changing to brown.....		Flesh-coloured ...	An amethyst bead, before blow-pipe, with borax or phosphate of soda and ammonia.
Nickel	Light green		Black	Cyanide of potassium gives a yellow-green precipitate.
Cobalt	Blue to green		Black	Cyanide of potassium gives a brownish white precipitate. Borax, in blow-pipe flame, a blue tint.
Iron Protoxide	White, then green, to brown..		Black	Ferrocyanide of potassium white to blue. Ferricyanide a deep blue.
Iron Peroxide.	Foxy brown	Sulphur precipitated.	Black	Ferrocyanide of potassium blue. Sulphocyanide of potassium blood-red colour.

CLASS V.—*Precipitated by Sulphuretted Hydrogen under all ordinary circumstances.*

Bases.	*Potash.*	*Sulphuretted Hydrogen.*	*Hydrochloric Acid.*	*Remarks.*
SILVER	Black, soluble in ammonia.	Black	White, curdy, changing through violet to black.	The chloride is characteristic.
MERCURY PROTOXIDE	Black, not soluble in ammonia.	Black	Dazzling white	Mercury is thrown down by copper.
MERCURY PEROXIDE.	Reddish bwn., changing to yellow as precipitant is added.	White, changing to black as precipitant is added.	None	Protochloride of tin precipitates metallic mercury as a grey precipitate.
LEAD	White, difficultly soluble in excess.	Black	White in concentrated solutions.	Sulphuric acid gives a white, chromate of potash, a yellow precipitate.
COPPER	Light blue or black...	Blackish brown	None	Ammonia in excess the beautiful blue compound.
BISMUTH......	White	Black	None	Bismuth is characterised by its tendency to form insoluble sub-salts.
CADMIUM	White	Bright yellow	None	The yellow sulphuret is very characteristic.

CLASS VI.—*A precipitate with Sulphuretted Hydrogen in Acid, but not in Alkaline Solutions.*

Bases.	*Potash.*	*Hydrosulphuret of Ammonia.*	*Sulphuretted Hydrogen.*	*Remarks.*
GOLD	Reddish yellow	Black, soluble in excess.	Black	Purple of Cassius with protochloride of tin; brown powder of metallic gold with protosulphate of iron.
PLATINUM ...	Yellow potassio-chloride.	Black, soluble in excess.	Blackish brown	The ammoniochloride is characteristic.

CLASS VI.—*continued.*

Bases.	*Potash.*	*Hydrosulphuret of Ammonia.*	*Sulphuretted Hydrogen.*	*Remarks.*
ANTIMONY	White......................	Orange, soluble in excess.	Orange red	The formation of a metallic mirror in Marsh's apparatus is characteristic.
TIN PROTOXIDE..	White, soluble in excess.	Brown, difficultly soluble in excess.	Dark brown	Perchloride of mercury is changed to protochloride; Perchloride of gold gives purple of Cassius.
TIN PEROXIDE ...	White, soluble in excess.	Yellow, soluble in excess.	Yellow	A ductile grain in the reducing flame.
ARSENIC	....	Vivid yellow in acid solutions.	Yellow	See the remarks at the end of that metal.

DIVISION II.—ACIDS.

CLASS I.—*Precipitated by Chloride of Barium.*

Acids.	*Chloride of Barium.*	*Other characteristic reactions.*
CHROMIC	Yellowish white	Is reduced by sulphuretted hydrogen and sulphurous acid; a yellow precipitate with acetate of lead.
SULPHURIC	White, insoluble in nitric acid	Acetate of lead, white; the baryta test is very characteristic.
PHOSPHORIC (Tribasic).	White, soluble in sal ammoniac	Solution of gypsum white, soluble in acids. Nitrate of silver yellowish; Acetate of lead white; Salts of magnesia white, especially on addition of ammonia.
BORACIC	White	Nitrate of silver white. Tinges the alcohol flame green.
HYDROFLUORIC...	White	Is readily distinguished by its action on glass.
CARBONIC	White	Escape of carbonic acid with dilute acids.

Class II.—*Acids precipitated by Nitrate of Silver.*

Acids.	*Nitrate of Silver.*	*Other characteristic reactions.*
Hydrochloric	White	Chlorine is evolved on heating with sulphuric acid and peroxide of manganese.
Hydrobromic	White	By like treatment bromine is evolved. Starch forms with free bromine a yellow colour.
Hydriodic	White	Add to solution 1 part of sulphate of copper and 2¼ protosulphate of iron, a dirty white precipitate falls. Free iodine gives a blue colour with starch. The purple vapour is characteristic.
Hydrocyanic	White	The odour of the free acid is characteristic; Peroxide of mercury is soluble in alkalies only in the presence of hydrocyanic acid.
Hydrosulphuric.	Black	The odour and action with lead salts are characteristic.

Class III.—*Acids which give no precipitate with Salts of Baryta or Nitrate of Silver.*

Acids.	*Separate reactions.*	*Reactions in common.*
Nitric	Acidify strongly with concentrated sulphuric acid. A crystal of sulphate of iron will communicate a dark brown tint; same with copper filings, nitrous oxide.	Deflagrate with charcoal and cyanide of potassium. Discolour solution of Indigo acidified with sulphuric acid on heating.
Chloric	Concentrated sulphuric acid liberates dark coloured oxide of chlorine; the action is violent, even to explosion.	

GLOSSARY.

The number denotes the paragraph in which the word occurs.

Absorption (*Lat.* suck up), the power of imbibing a fluid, 31.
———— **of Gases by water**, 31.
Acetic Acid (*Lat.* vinegar), the acid of vinegar.
Acicular (*Lat.* a needle), pointed like needles.
Adhesiveness (*Lat.*), the power of sticking together.
Aëriform (*Lat.*), having the form of air.
Affinity (*Lat.* relationship), force which causes bodies to unite, 156.
Alcohol (*Arab.*), the spirituous part of spirits of wine.
Alkali (*Arab.*), hot burning substance, as quick-lime, 195.
Alloys, the mixtures formed by melting two metals together; these are described at the end of the respective metals.
Aluminum (*Lat.*), the metal of alumina, 295.
Amalgams (marry together), the alloys of mercury, 468.
Amorphous (*Gr.*), without form.
Ammonia, a pungent gas, 44, 45.
Ammonium, the name of a hypothetical metal, 245.
Amides, the name given to anhydrous ammoniacal salts, 252.
Analogy (*Gr.*), relative proportion, or similarity.
Analysis (*Gr.*), the discovery of component parts.
Anhydrous (*Gr.*), containing no water, 32, 155.
Anomalous (*Gr.*), not according to rule.
Antimony (*Fr.*), a metal used in type, 432.
Aqueous (*Lat.* water), of or belonging to water, 25.
Aqua Regia (*Lat.* royal water), nitrohydrochloric acid, 89.
Arsenic, a poisonous metal, 445.
Axis (*Gr.*), an imaginary line drawn through a crystal, 191.
Atom (*Gr.*), that which cannot be divided; a minute particle, 145.
Atmosphere (*Gr.*), the air which surrounds the globe, 49.
Azote (*Gr.* without life), another name for nitrogen, 36.

Balance, a pair of scales, 519.
Barium (*Gr.* heavy), the name of a metal, 273.
Barometer (*Gr.* weight-measurer), an instrument which measures the weight of the atmosphere, 49.

BINARY (*Lat.* twofold), that which consists of two elements or substances.
BISMUTH, a heavy metal resembling lead, 369.
BORON (from Borax), an element, 113.
BROMINE (*Gr.* stinking), an element, 103.

CADMIUM, a metal found with zinc, 367.
CALCIUM (*Lat.* lime), the metal of lime, 260.
CALOMEL, the old name for protochloride of mercury, 458.
CAPILLARY (*Lat.* a hair), hair-like.
CAPSULE (*Lat.*), a shallow cup.
CARBON (*Lat.* a coal), an element, 54.
CATALYSIS (*Gr.* to let loose), sometimes called disposing affinity, 162.
CAUSTIC (*Gr.* to burn), hot, burning, as quick-lime.
CAUTERY, a chemical substance which eats into the flesh, 198.
CHLORINE (*Gr.* green), an element, 86.
CHROME (*Gr.* colour), a metal used in dyeing, 395.
CHRYSOCOLLA, impure borax, 113.
CINNABAR, the old name for sulphuret of mercury, 463.
CLEAVAGE PLANE, the surface in which crystals split, 188.
COAL GAS, the gas distilled from coal, 61.
COBALT (*Ger.* a kobbold), the metal in smalts, 353.
COLCOTHAR, the old name for peroxide of iron, 322.
COLUMBIUM, a metal also called tantalum, 425.
COMBUSTION (*Lat.* a burning), chemical combination, disengaging light and heat, 62.
CONDENSATION (*Lat.*), pressing into less space.
CONDUCTOR (*Lat.* lead together), that which has the power of transmitting heat and electricity, as metals do.
CONTRACTION (*Lat.* to grow small), diminution of bulk.
CONVECTION (*Lat.*), transmitting heat by currents, as liquids do.
COPPER (*Gr.* Cyprus), a well-known metal, 379.
COPPERAS, the old name for sulphate of iron, 331.
CORROSIVE SUBLIMATE, perchloride of mercury, 459.
CRYSTALLOGRAPHY (*Gr.*), the science of crystals, 186.
CRYSTAL (*Gr.* ice), a regular solid, 185, 547.
CRUCIBLE (*Lat.* a cross), a pot in which metals are melted, 553.
CUPEL, a shallow cup of bone earth, 472.
CYANOGEN (*Gr.* blue-generator), a radicle, the basis of Prussian blue, 127.

DAVY LAMP (called after Sir H. Davy), a lamp used by miners, 64.
DECOMPOSITION (*Lat.*), resolution into elements, 159.
————, DOUBLE, 159.
DECANTATION (*Lat.*), pouring off a solution from a precipitate, 545.

Decrepitate (*Lat.* to crackle), to fly in pieces when heated, as salt does, 224.
Deflagration (*Lat.* a burning), generally used of combustion with nitre.
Deliquesce (*Lat.* grow liquid), absorb moisture from the air, 50.
Density (*Lat.* thick), often used in the same sense as specific gravity, 27.
Desiccation (*Lat.* a drying), the act of drying substances, 548.
Detonate (*Lat.* to thunder), to explode.
Diaphragm (*Gr.*) a division, as of bladder.
Dilatation (*Lat.* grow larger), expansion.
Dimorphous (*Gr.* two-formed), explained, 192.
Disintegration, separation of the particles.
Distillation (*Lat.* separate, drop by drop), the conversion of vapour into a liquid, 535.
Dodecahedron (*Gr.*), having twelve sides, 189.
Ductile (*Lat.* to lead), the property in metals which admits of their being drawn into wire, 165.

Ebullition (*Lat.*), boiling.
Efflorescent (*Lat.* flowery), said of salts which crumble to powder by losing water.
Element (*Lat.*), that which cannot be decomposed.
Empirical (*Gr.*), by trial.
Empyreumatic (*Gr.*), smelling of fire, as tar.
Equilibrium (*Lat.*), balancing.
Equivalent (*Lat.* equal worth), the weight in which an element combines, 132.
Eudiometer (*Gr.*), an instrument for determining the purity of the air.

Fermentation (*Lat.*), the process by which spirits are produced.
Ferrocyanogen (a mixed Latin-Greek word, meaning iron-blue generator), a radicle, 336.
Filter, a strainer, 544.
Fire-damp, a name given to carburetted hydrogen, 59.
Fluorine (*Lat.* to flow), an element found in fluor spar, 107.
Flux, a substance promoting fusion, 556.
Formula (*Lat.*), a general rule of expression.
Friction (*Lat.* to rub), the rubbing or grating of surfaces.

Galvanism (from Professor Galvani), a kind of electricity.
Gas, an incondensible vapour.
Gold, a well-known metal, 485.
Goniometer (*Gr.* an angle), an instrument for measuring the angles of crystals.
Gravitation (*Lat.* heavy), the power which makes bodies fall to the ground.

Gravity, Specific, explained at 27, 53.

Glucinum (*Gr.* sweet), metal resembling aluminum, 301.

Hermetic Seal (from Hermes, the name of a Greek deity), the sealing up the end of a glass tube by melting it.

Homogeneous (*Gr.*), of the same kind throughout.

Hydrate (*Gr.*), a combination of water, 32.

Hydrogen (*Gr.* water producer), one of the constituents of water, 9, 22.

Hydracid (*Gr.*), an acid in which hydrogen is the acidifying principle, 180.

Hydrometer (*Gr.* water measurer), an instrument for taking specific gravities of fluids.

Hyper (*Gr.* preposition, signifying excess).

Hypo (*Gr.* preposition, signifying deficiency).

Hypothesis (*Gr.*), a theory or supposition.

Incandescent (*Lat.* glowing), red or white hot.

Inflammable (*Lat.*), that which will burn.

Interstices (*Lat.*), the spaces or cracks in solids.

Iodine (*Gr.* a violet), an element, 99.

Iridescent (*Gr.* a rainbow), coloured like the rainbow.

Iridium (*Gr.* a rainbow), a scarce metal, 502.

Iron, a well-known metal, 320.

Isomeric (*Gr.* equal parts), said of bodies which consist of the same elements but yet have different properties, 136.

Isomorphous (*Gr.* equal formed), said of bodies which replace each other without change of form, 193.

Lamp, used in chemistry as a source of heat, 525.

Lead, a well-known metal, 386.

Lithium (*Gr.* a stone), a metal like sodium, 257.

Lixiviation, dissolving soluble from insoluble substances, 534.

Lute, a plaster which prevents the escape of gas, 569.

Malleable (*Lat.* a hammer), capable of being beaten into plates, 164.

Magnesium (the name of a place), the metal of magnesia, 287.

Manganese, a metal, 309.

Manipulation (*Lat.* a hand), the method of conducting experiments, 517.

Metallurgy (*Gr.*), working in metals.

Mercury (*Lat.* a Latin deity), the metal quicksilver, 455.

Meta (*Gr.* preposition), change.

Meteoric, that which comes from the clouds, the region of meteors, 320.

Molecules (*Lat.*), the particles of bodies.
Molybdinum (*Gr.* lead ore), a scarce metal, 416.
Multiple, a number which is double, treble, &c., one-half, one-third, &c., another.
Muriatic Acid, the old name for hydrochloric acid.

Nitrogen (*Gr.* nitre generator), an element, 34.
Nickel (*Ger.* false, bastard), a metal used in German silver, 346.
Nodules, small lumps.
Nomenclature (*Lat.* giving names), the method of giving names to chemical substances, 150.
Normal (*Lat.*), according to rule.

Octohedron (*Gr.*), that which has eight sides.
Oil of Vitriol, the old name for sulphuric acid, 70.
Olefiant Gas (*Lat.* oil making), see 60.
Organic (*Gr.* an instrument), that which is derived from animals or vegetables.
Orpiment (*Lat.* gold paint), tersulphuret of arsenic, 449.
Osmium (*Gr.* odour), a rare metal, 515.
Oxygen (*Gr.* acid generator), the vital part of the air we breathe, 4.

Palladium (*Gr.* name of a deity), a scarce metal, 502.
Para (*Gr.* preposition), alongside.
Pellicle (*Lat.* a skin), a skin or crust formed on the top of a liquid.
Percolate (*Lat.* strain through).
Phosphorus (*Gr.* light producer), an element, 117.
Physics (*Gr.* natural), a branch of natural science.
Pipette (*Fr.*), an instrument for drawing off small quantities of liquid, 546.
Platinum, an infusible metal, 491.
——— trough, 550.
Pneumatics (*Gr.* wind, air), the science of the properties of gases.
Potassium, the metal of potash, 195.
Pounxa, impure borax, 113.
Precipitate (*Lat.* to let fall), the solid matter which falls from the liquid, 543.
Product (*Lat.*), the result of an operation.
Prussiates, the old name for ferrocyanides, 337.
Pyrometer (*Gr.* fire measurer), an instrument for measuring high temperatures.

Qualitative Analysis (*Lat.*), finding out the nature of substances, 337.

Quantitative Analysis (*Lat.*), determining the exact quantity of each substance present.

Radicle (*Lat.* a root), a compound which behaves like an element, 127.
Realgar, protosulphuret of arsenic, 448.
Refrigeration (*Lat.*), cooling.
Retort (*Lat.* bent back), a chemical vessel with a bent neck, 536.
Rhodium (*Gr.* a rose), a scarce metal, 509.
Ruthenium, a scarce metal, 514.

Salifiable, base (*Lat.* able to make salt), an oxide capable of forming a crystalline combination with an acid, 179.
Salt, a compound of an acid with a base, 46, 179.
Saltpetre, the old name for nitre, or nitrate of potash, 208.
Sapid (*Lat.* to taste), that which has a taste.
Saturate (*Lat.* filled), a solution is said to be saturated when it can dissolve no more, 532.
Selenium (*Gr.* moon), an element resembling sulphur, 81.
Silicium (*Lat.* a flint), the basis of flint, 109.
Silver, a well-known metal, 470.
Smalt, the name of a pigment prepared with cobalt, 353.
Solvent (*Lat.* dissolve), that which will dissolve anything.
Sodium, the metal of soda, 221.
Spelter, another name for zinc, 361.
Sphere (*Gr.*), a ball or globe like the earth.
Strontium (from Strontian, in Argyleshire), an earth metal, 283.
Stratum (*Lat.*), a layer.
Sublimation (*Lat.* high), condensing a vapour into a solid, 425, 542.
Sulphur (*Lat.*), sometimes called brimstone, 67.
Symmetrical (*Gr.* measuring together), having parts corresponding and alike, 190.
Symbol (*Gr.* to put together), that which represents anything, 144.

Tenacity (*Lat.* strong), strength of metals, 167.
Tantalum (*Gr.*), a rare metal, 425.
Tellurium (*Gr.* the earth), a rare metal, 442.
Ternary (*Lat.* threefold), that which consists of three.
Test Paper, paper stained with litmus, &c. 549.
Tetrahedron (*Gr.*), a body having four triangular sides, 189.
Thermometer (*Gr.* heat measurer), an instrument for measuring heat.
Tin, a well-known metal, 405.
Tincal, the name of impure borax, 113.
Titanium (a Greek deity), a rare metal, 429.
Torsion (*Lat.*), twisting.

Trituration (*Lat.* to rub), a grinding to powder in a mortar, 530.
Transparent (*Lat.*), that which may be seen through.
Truncate (*Lat.* maimed), that which is shortened or cut off, 187.
Tungsten, a metal sometimes called wolfram, 413.
Tube (*Lat.* a pipe), a pipe of glass or other substance, 559.

Uranium (*Gr.* deity), a metal, 375.

Vanadium (Vanadis), a scarce metal, 420.
Vermilion, the old name of sulphuret of mercury, 463.
Vesicular (*Lat.* a bladder), that which is formed of bubbles.
Vitriols, the old name for salts of sulphuric acid.
Volume (*Lat.* a roll), the space occupied by a body, 142.

Zaffre, a blue colour prepared with cobalt, 360.
Zero, the numeral 0.
Zinc, a metal sometimes called spelter, 361.

R. CLAY, PRINTER, BREAD STREET HILL.